A study of the Malaysian national innovation system: Commercialisation of public university research output.

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A STUDY OF THE MALAYSIAN NATIONAL INNOVATION SYSTEM: COMMERCIALISATION OF PUBLIC UNIVERSITY RESEARCH OUTPUT

by Riaz Abdul Razak

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DECLARATION

This work has not previously been accepted in substance for any degree and is not being concurrently submitted in candidature for any degree.

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LIST OF ABBREVIATIONS

8MP	Eighth Malaysia Plan
BDU	Business Development Unit
CRDF	Commercialisation of R&D Fund
GERD	Gross Expenditure on Research and Development
GRI	Government Research Institutions
ICT	Information and Communication Technology
IHL	Institutes of Higher Learning
IP	Intellectual Property
IRPA	Intensity of Research on Priority Areas
ISIS	Institute of Strategic and International Studies
KDI	Knowledge-Based Economy Development Index
KEMP	Knowledge-Based Economy Master Plan
KHTP	Kulim Hi-Tech Park
MARDI	Malaysian Agriculture Research and Development Institute
MASTIC	Malaysian Science and Technology Information Centre
MIGHT	Malaysian Industry-Government Group for High Technology
MIPC	Intellectual Property Corporation of Malaysia
MOSTI	Ministry of Science, Technology and Innovation
MTDC	Malaysian Technology Development Corporation
NCSRD	National Council for Scientific Research and Development
NIS	National Innovation System
OECD	Organisation for Economic Cooperation and Development
OPP3	Third Outline Perspective Plan
R&D	Research and Development
S&T	Science and Technology
SME	Small and Medium Scale Enterprise
STEP2	Second National Science & Technology Policy
TAF	Technology Acquisition Fund
TDC	Technology Development Clusters
TLO	Technology Licensing Offices
TPM	Technology Park Malaysia
VC	Venture Capital
WEF	World Economic Forum

ABSTRACT

The purpose of this study is to explore the Malaysian national innovation system with respect to the process of technology transfer from public universities to industry. Much academic literature published on technology transfer focuses on measuring quantifiable knowledge outputs such as patents and publications, or the impact of policies and funding. However, it was found that such approaches might not be applicable to developing nations such as Malaysia due to a small indigenous technology base. With this in mind, the study attempts to identify the roles of the various stakeholders within the Malaysian national innovation system, and the linkages that had evolved between them with regards to commercialising research outputs.

The scope of the study is limited to commercialisation of research findings as compared to other forms of technology transfer such as consultancies and movement of human resources. To collect data, the study makes use of semi-structured interview questionnaires and experience interviews with researchers, policymakers, and industry representatives, as well as visits and observations to relevant institutions and organisations.

The results of the study indicate that university researchers are increasingly aware of the commercial viability of their research, and have taken steps towards protecting their intellectual property with a view to licensing it to industry. The Malaysian government on its part is found to be supportive of collaborations between university and industry, yet organisational fragmentation remains a problem as many government agencies are competing for the same funds and authority. However, the private sector appears to be unwilling to take up research output from universities, due to factors such as a low rate of technology absorption among firms and a focus on short-term profits.

Recommendations are proposed to address these issues, such as increasing the standards of research management within universities, improving the main public research funding mechanisms, as well as providing fiscal incentives for higher value-added activities to be conducted by industry. In conclusion, the Malaysian national innovation system has benefited from strong policies and well-planned frameworks, however there is room for progress on the implementation of such policies and the strengthening of linkages between university and industry.

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1.0 CHAPTER I – INTRODUCTION

This chapter outlines what the study intends to do and the research issues that need to be addressed. The chapter also presents the rationale and significance of the study. The research aims and objectives will be explained. The study is set in Malaysia, which is one of the most rapidly developing countries in South East Asia. Malaysia is moving from a manufacturing and export-based economy towards a knowledge-based economy, with a growing awareness of the value of intellectual capital. This is reflected through attempts at the commercialisation of public research output, which is the focus of the study. The setting of the study is explained.

1.1 Statement of the problem

For the past two decades, universities worldwide have experienced a significant increase in technology transfer activities, with an especially high growth rate in the United States and the United Kingdom [AUTM, 2004; UNICO, 2003]. This is mainly due to the decreasing trend of governmental collaborations. Legislation is often cited as a major catalyst in pushing universities to be more actively involved in transferring their research findings to industry partners for entry into the market. A clear example is that of the Bayh-Dole Act passed by the U.S. Congress [1980], which guaranteed universities the rights to protect and license inventions derived from public funded research, thus promoting transfer and applications from such research for the benefit of the inventors, their universities and the greater public.

In view of this situation, university administrators worldwide have accepted that technology transfer should be a legitimate function of their third mission activities - to co-operate with organisations and companies, associations and individuals to be able to contribute to local and regional development [Etzkowitz and Leydesdorff 1997]. There is an increasing trend amongst universities to focus on promoting regional economic impact from their research efforts [Garlick, 2002]. National policymakers are also drafting various initiatives on how to promote and encourage such activities within their countries. These initiatives range from launching venture capital funds promoting innovative entrepreneurship, to setting up cluster-based science parks and incubators, and drafting similar legislation to the Bayh-Dole Act in the hope of increasing the amount of research transfer activities.

These measures are timely given the current global shift towards a knowledge-based economy, defined by the Organisation for Economic Cooperation and Development (OECD), as economies being "directly based on the production, distribution and use of knowledge and information" [OECD 1996]. It is in this context where universities, as producers of intellectual as well as human capital, will become strategic national assets with the support of strong industry linkages. This is especially important in the case of developing countries where strong emphasis on intellectual and human capital can make up for the lack of traditional economic assets such as land and natural resources.

This study is intended to present an indication of technology transfer activities from universities to industry in Malaysia, in the context of a developing country in transition from a production-based economy to a knowledge-based economy. This study begins with the assumption that there is no effective flow of technology as produced from research efforts of academia to the private sector. The question then arises: Is there a strategy to channel university knowledge to industry, with proper support from the government? The study shall attempt to examine the role of universities, industry and the government in this perspective and the linkages that have evolved between them.

The approach taken will be in the form of an exploratory study, relying mainly on qualitative data. This study will inevitably be interdisciplinary in nature, due to the multitude of themes involved. It begins with a review of several public policies on science and technology, and how such policies are implemented worldwide. It will touch on identifying critical growth areas such as engineering knowledge and life sciences that can be marketed by academia to industry. It will refer to legal aspects of intellectual property and contract law, which involves negotiating proprietary rights equitable to the parties involved. It will also cover competitive strategy, business ethics and the dynamism of the laws of economics that determine market forces. Because the study is based in a Malaysian context, it is also necessary to examine the cross-cultural practices and socio-political considerations as found in the local setting.

1.2 Background and Rationale of Study

Past and present work done by the University of Wales Swansea, centre around various efforts that encourage collaboration between the university, foreign multinational companies, the Welsh Development Agency and the Welsh Assembly.

The most visible of these initiatives is the Technium concept, grouping together start-up companies, entrepreneurs, multinational blue-chip companies and university research expertise under one roof. Further discussions with the academic partners of the Technium project led to the notion of an exploratory study on similar state-of-the-art efforts going on in Malaysia. A literature check revealed no such study has been done to report sufficiently on the Malaysian setting. A systematic and informed study of this state of affairs is therefore timely and relevant.

In some ways, Wales and Malaysia seem to offer a basis for comparison. Wales appears to be in a similar transition phase as Malaysia, with the same needs to have innovative models that can operate in more inventive ways in their pursuit of rapid development. As with Wales, Malaysia's growth as a knowledge economy is partly dependent on the marketing of intellectual capital developed by academia.

This study will, in a small way, contribute to a broader body of work, conducted by the K-Economy Research Group, which is intended to gather information on the readiness of nations striving towards a knowledge-based economy. It is within this context that a study carried out on Malaysia will be valuable in evaluating the experience of a newly industrialized economy, which is attempting to utilize its research capacity as a step forward towards becoming a knowledge-based economy.

1.3 Significance of the Study

Today, countries, regions and cities are competing to attract and retain successful knowledge-based businesses, clusters and industries, because they recognise the dynamic contributions these can make to their economic success and societal development. While higher education institutions have always been in the business of research and innovation, and of knowledge generation and transfer, as well as fulfilling their wider responsibilities to society, today universities are a critical success factor at the heart of successful, competitive knowledge based economies, of learning countries, regions and cities; and of learning and innovative industries, clusters and businesses. Success in exploiting new knowledge to develop innovative products, processes and services is a key not only to creating and sustaining competitive advantage but also to business survival. Therefore, it is clear that there is a growing need for universities to adjust their third mission activities.

The Lambert Review of Business-University Collaboration prepared by the Treasury in 2003, concurs with this, stating:

> *Universities will have to get better at identifying their areas of competitive strength in research. Government will have to do more to support business-university collaboration. Business will have to learn how to exploit the innovative ideas that are being developed in the university sector.*
>
> [HM Treasury 2003]

The Malaysian government has stated its intent in propelling Malaysia towards a knowledge-based economy, as outlined in the "K-Economy Master Plan" drafted by the Institute of Strategic and International Studies, under the guidance of a committee from the Ministry of Finance. One of the strategic thrusts intended to achieve this goal is to "... increase capacity for the acquisition and application of science and technology... in all areas" [ISIS 1999]. The gap in technological development and achievements between Malaysia and other developing and developed countries is widening.

Therefore, there is a serious need to raise awareness and understanding that improving indigenous technology and innovation capabilities can and must make an important contribution to the development of a knowledge-based economy.

1.3.1 Context of research

Since the late 1990s, several attempts have been made to evaluate and to compare innovation systems in terms of their performance, which in turn is defined and measured in different ways. In some cases, comparative studies on the system-level have been utilized as a preliminary step to generate rankings of national innovation systems (NIS) [Porter and Stern 2002]. They can be classified in policy-oriented studies and in research-driven advancements of the NIS approach.

The growing number of policy-oriented studies of innovation systems signals that the creation of innovation-enhancing framework conditions has become a central target of policymakers around the globe, and particularly in highly industrialized countries. Due to the pragmatic assumptions underlying the NIS concept, and due to the insightful outcomes gained so far from studies of national innovation patterns, the systemic approach to innovation enjoys growing popularity among policymakers as a means to derive technology policy implications. There are clearly commonalities to be closely examined to achieve similar aims, and therefore this establishes the Malaysian context for such a study.

1.3.2 Research Parameters

As the research is conducted in Malaysia, the parameters for the research have to be more controlled due to time and cost limitations. The scope of this thesis is limited to research on public universities using public funding, as this will give a better demonstration on how the available resources are effectively utilized under an existing structure with established delivery systems and linkages. The data collected through primary data collection methods covers the period between 2002 to the end of 2004.

This study is not meant to be a comprehensive review on technology transfer in Malaysia, as it will examine the evolving roles and linkages between the parties involved in the Malaysian national innovation system, rather than measuring the numbers of introduced products and process innovations. The outputs of successful transfer of technology will also be limited to commercialisation of research findings, with less emphasis on university spin-off companies and consultancies.

Previous studies which have been conducted focussed on assessing technological innovation purely on the basis of patents and products [Comanor and Scherer, 1969; Narin, 1995; Liu and White, 2001]. This approach is suitable for industrialized countries with established provisions for intellectual property rights. This study however will follow the trends outlined by Balzat & Hanusch [2004], which concentrates on analyzing the development stage of the national system of innovation, with emphasis on historically grown patterns and institutional frameworks. This approach is more suited towards industrializing nations and emerging innovation structures and organisations, as in studies published by Radosevic [1999] or Paasi [1998].

1.4 Research Aims and Objectives

The principal aim of the research is to explore the process of technology transfer from Malaysian public universities to the private sector. To achieve this, the main participant organisations and institutions involved, as well as the significant stakeholders, will have to be identified. Their roles will be explained.

The inputs necessary for the effective flow of technology, as well as the resultant outputs will be examined, as these are imperative in recognizing critical factors that affect the process.

The study will provide information that will give an indication of the state of the linkages between universities and industry facilitated by the government, and from this a conclusion can be made on whether Malaysia has a strategy for effectively utilizing research findings.

In order to meet the aims above, the research was designed with specific objectives in mind. These are:

i) to identify the main stakeholders and key players of the national innovation system;

ii) to detail the roles of relevant government agencies and policies;

iii) to investigate issues related to commercialisation of research output from public universities;

iv) to explore the involvement of the private sector in research & development;

v) to contribute to an understanding of how and why technology from public research findings is being utilized by the private sector.

To meet these objectives the study will make use of various literature sources on technology transfer and the knowledge-based economy around the world, especially in the United States. This knowledge will then be applied to the Malaysian setting, where secondary data sources such as public sector policy papers and current literature on Malaysia will be examined to determine how the national innovation system is taking shape and in which direction it is heading.

Primary data will be obtained through experience interviews, questionnaires and discussions with researchers, policymakers, venture capitalists and other practitioners, attending exhibitions, seminars and conferences as well as visits to observe research and research-related activity in universities, government agencies and technology incubators to talk to the relevant parties.

1.5 Overview of the Malaysian setting

1.5.1 Economy

The Malaysian economy began with a heavy reliance on subsistence agriculture, before the emergence of Malacca as an entrepot trading empire in the 16^{th} century.

One of the effects of colonisation was that the peasant society was introduced to labour intensive agriculture and industrial mining of tin and rubber; and in the process an influx of immigrant labour from China and India was brought into the country. After independence in 1957, the economy entered a state of transition from an industry based on producing raw materials to a light industrial and commercial agricultural society.

Alongside the other 'Asian tigers', Malaysia has proved to be successful in industrial manufacturing, with high value-added production but low research & development, no doubt influenced by a strong presence of foreign direct investment [Evers, 2001]. Unfortunately, the electronics sector – Malaysia's key export - was hit hard due to the Asian financial crisis in 1997 and the slump in the information technology sector in 2001, and as a result, new areas for sustainable growth are being investigated. The current statistics for Malaysia's macroeconomic indicators are presented in Figure 1.1.

Population (millions)	25.05
Land Area (km2 '000)	329.70
Exchange rate (per $)	3.80
GDP ($ billion)	103.20
GDP per capita ($)	4,118
Real GDP growth (%)	5.20
Labour force (millions)	10.34

Fig. 1.1 Macroeconomic statistics of Malaysia, 2003
(Malaysian Department of Statistics, 2003)

Malaysia has experienced a recent drop in competitiveness, with a ranking of 29 out of 70 nations, as shown by the Growth Competitiveness Index 2003 in Figure 1.2, produced by the Institute of Management Development (IMD). The Growth Competitiveness Index ranks 70 countries based on more than 250 different criteria (such as economic performance, technology, government and business efficiency, and infrastructure). Countries are ranked from the most to the least competitive according to their index value. The United States has led the rankings since the first survey until 2003, when Finland reached the top ranking. The gradual slide in Malaysia's rankings began in 1997, possibly due to the East Asian financial crisis, and slowed down the upward trend from previous years. It would be pertinent to note, however, that Malaysia scored relatively highly on the technology index, with a ranking of 20 out of 70 countries surveyed [WEF, 2004].

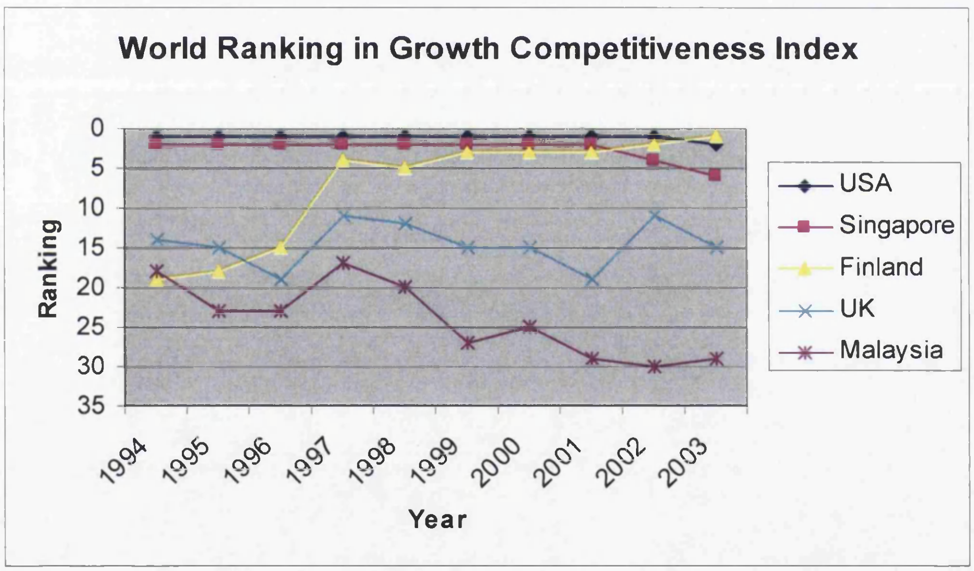


Figure 1.2 – Rankings of selected nations in the Growth Competitiveness Index [IMD, 2004]

1.5.2 Education

Education in Malaysia broadly consists of a set of stages, from pre-school, to primary, secondary and tertiary education, and up to the postgraduate level. Only primary school education in Malaysia is mandatory by law, hence it is not a criminal offence to neglect the educational needs of a child after he or she has completed the first six years.

Primary and secondary education in government schools is managed and funded by the Ministry of Education, but policies and funding of tertiary education come under the purview of the Ministry of Higher Education, created in 2004. Prior to that, all lecturers in public tertiary institutions were required to have some post-graduate award as a requisite qualification. In October 2004, this requirement was removed and the Higher Education Ministry announced that industry professionals who added value to a course could apply for lecturing positions directly to universities even if they did not have postgraduate qualifications.

There are currently 17 local public universities and one international university (International Islamic University of Malaysia). While these are heavily subsidized by the government, there are also private institutions of higher learning, which currently consist of 13 private universities, 4 foreign university branch campuses and one university college. The yearly student intake of these institutions of higher learning combined come to 800,000 students, of which 15,000 come from overseas. [Malaysian Department of Statistics, 2003].

1.5.3 Legislative Structure

Malaysia is a constitutional monarchy, nominally headed by the *Yang di-Pertuan Agong* (literally meaning "paramount ruler"), and customarily referred to as the King. Kings are elected for 5-year terms from among the nine sultans of the peninsular Malaysian states. The king is also the leader of the Islamic faith in Malaysia.

Legislative power is divided between federal and state legislatures. Malaysia has two constituencies of law. One is for the entire nation and is sovereign, which has been set by the parliament. The highest of this is the constitution and requires a two-thirds majority to amend. However, the ruling party has never had less than this number. The federal government has authority over education, external affairs, defence, internal security, justice, federal citizenship, finance, commerce, industry, communications, transportation, and other matters. The second constituency of law is *syariah* (Islamic law) which applies only to Muslims in this country.

The Malaysian legal system is based on English common law. However, most of the laws and the constitution are lifted from Indian law. The Federal Court reviews decisions referred from the Court of Appeals; it has original jurisdiction in constitutional matters and in disputes between states or between the federal government and a state. Peninsular Malaysia and the East Malaysian states of Sabah and Sarawak each have a high court.

1.6 Structure of Thesis

This thesis will be presented in six chapters. Chapter I gives the fundamentals of the research area and the research process. Chapter II begins with a summary of available literature on the knowledge economy and the production of knowledge, before reviewing the literature concerning national innovation systems and the transfer of technology between the organisations involved. The literature review also considers different approaches taken to achieve linkages between universities and industry. Chapter III will describe the methodology taken in this study and how the research was designed to meet those needs. The sources of data that were collected and their relevance to the study will be highlighted as well.

Chapter IV presents an outline of the current situation in Malaysia concerning the national innovation system. The participant organisations and institutions will be identified and the roles that they play in this process described. The findings of the study will be presented in Chapter V, together with a discussion of related issues. It is hoped that a clearer picture will emerge of the state of affairs with respect to technology transfer of research put from public universities to the private sector with the intervention of public agencies and policies. Chapter VI is the final chapter where limitations of the study will be discussed. This chapter also highlights significant contributions of, and recommendations arising from, the study.

2.0 CHAPTER II – REVIEW OF LITERATURE

This literature review begins with a summary of available literature on the knowledge economy and its importance as a driver for economic development. Next, the review focuses on the production of knowledge from universities, before moving on to an examination of science policies in developing countries. Different approaches to university linkages will be highlighted. The literature review will continue with a look at technology transfer as practised in the United States, from legislation to patenting. This section will conclude with an examination of the Hungarian national innovation system.

2.1 Knowledge Economy

2.1.1 The basic concept of a knowledge-based economy

The knowledge-based economy has been explained in many different ways by different writers, which is not surprising for a relatively new concept. One of the earlier attempts to shed light on the subject by Arthur [1995] referred to the knowledge-based economy as the information economy, in which information technology (IT) plays a major role in determining a nation's competitive advantages [Arthur, 1995]. Another point of view, prominently brought forward during a special European Council held in May 2000 in Lisbon, considered IT central to explaining the 'New Economy' that couples high productivity and economic growth with low costs [Freeman and Soete, 1994; Heller and Eisenberg, 1998]. Other concepts of the knowledge-based economy include the cyber economy, network economy, "E-conomy", and information economy.

As mentioned in the previous chapter, the Organisation for Economic Cooperation and Development (OECD) defines a knowledge-based economy as an economy that is directly based on the production, distribution and use of and information. This means that knowledge is regarded as the core factor of production, as compared to traditional economic production functions of land, labour, capital, materials and energy. It is interesting to note that knowledge was considered to play an important role in building economies since as early as the 18th century, when Adam Smith in his revolutionary work "The Wealth of Nations" referred to his 'philosophers and men of speculation', men who made important contributions to the production of economically useful knowledge [Smith, 1986].

As knowledge is a difficult commodity to quantify, the OECD makes a clear distinction between different kinds of knowledge that are important in the knowledge-based economy, to aid in incorporating knowledge into standard economic production functions.

- *Know-what* refers to 'knowledge about facts', close to what is normally called information – it can be broken down into bits. In some complex areas, experts must have a lot of this kind of knowledge in order to fulfil their jobs. Practitioners of law and medicine belong to this category.

- *Know-why* refers to knowledge about the principles and laws of nature. This kind of knowledge underlies technological development and product and process advances. The production and reproduction of know-why is often organised in specialised organisations, such as research laboratories and universities. To get access to this kind of knowledge, firms have to interact with these organisations either through recruiting scientifically trained labour or directly through contacts and joint activities.

• *Know-how* refers to skills or the capability to do something. Executives judging market prospects for a new product, or a personnel manager selecting and training staff need to use their know-how. The same is true for the skilled worker operating complicated machine tools. Know-how is typically a kind of knowledge developed and kept within the border of an individual firm. One of the most important reasons for the formation of industrial networks is the need for firms to be able to share and combine elements of know-how.

• *Know-who* involves information about who knows what and who knows how to do what. It involves the formation of special social relationships that make it possible to get access to experts and their knowledge. It is significant in economies where skills are widely dispersed because of a highly developed division of labour among organisations and experts. For the modern manager and organisation, is important to use this kind of knowledge in response to the acceleration in the rate of change. Know-who knowledge is internal to the organisation to a higher degree than any other kind of knowledge.

Among the above listed four different kinds of knowledge, "know-what" and "know-why" are closest to what is normally called information, and represent codified knowledge because they can be commoditised (relatively) easily and disseminated. The last two components of knowledge, "know-how" and "know-who", otherwise known as “tacit knowledge”, are classified as uncodified knowledge and as such are slow and costly to measure, transmit and absorb. [Lundvall and Johnson, 1994; Teece, 1998].

In general, “information” refers to codified knowledge. Thus, when the word “knowledge” is used with “information” it would indicate tacit knowledge. However, if the word “knowledge” is used isolated from “information”, it refers to all four components of knowledge listed above [Lee, Chang et al, 2000].

Technology transfer can thus be seen as the transfer of codified knowledge between two parties, with the best example being the licensing of patents from university researchers to industry. Since the commodity has been quantified and measured, it can be then incorporated as an economic production function, similar to capital or labour.

There are also other views on the knowledge economy, which concentrate on the use of information technology (IT), as described by Arthur [1995] and others which were mentioned previously. IT does play a major part in the knowledge economy by increasing the speed at which information travels, and also by increasing the reach of such information by reducing the ‘distances’ between parties. However the transfer of codified knowledge can just as well happen when information is written on a piece of paper and passed between two people.

Therefore this study will look at the use of codified knowledge, i.e.” know-what” and “know-how”, as the successful dissemination of such knowledge is an integral part for effective transfer of technology. Specifically, this study will observe the generation of research outputs from university and how it will be transferred to industry for application and dissemination to the market.

2.1.2 The importance of the knowledge-based economy

The knowledge capacity of a nation, and by extension the technological capacity, has usually been neglected as a strategic factor in traditional economic production comparison studies. However, since production is a result of the transformation of resources into commodities, and resources such as land and capital are scarce, production must be accomplished by capitalizing on the usage of resources in ways that generate increasing returns on investment [World Bank, 1998]. Peter Drucker was one of the earliest to point this out, and he suggested that '...knowledge is now becoming the one factor of production, sidelining both capital and labour' [1993]. Other eminent economists have been developing analytical approaches and growth theories so that knowledge can be included more directly in production functions [Romer, 1990; Grossman and Helpman, 1991].

Investment in knowledge can increase the productive capacity of the other factors of production as well as transform them into new products and processes. Perhaps not coincidentally, the fixed costs of production for such knowledge-intensive products are large, but the variable costs of production tend to be small. This cost structure thus allows knowledge-based industries substantial economies of scale [Lee and Gibson, 2002]. Therefore, we can say that knowledge and technology are the key to modern economic growth [OECD, 1996].

However, knowledge, once created, can in some cases be readily accessed by the public, and it is difficult for the creator to prevent others from using it, for example the reverse-engineering of software code. Teece notes that if this knowledge is used or diffused without some form of compensation to the creator, this reduces the gains to innovators, who then have diminished incentive to invest in the costly R&D to generate the knowledge in the first place [1998]. This, and other factors make it necessary for some form of provision to protect the rights of the original owner or creator of such knowledge, or what is now commonly known as intellectual property rights.

The effective use of knowledge is not confined to acquire monetary gain, as it is also important in terms of social well-being and quality of life. Examples of these include research on methods to cure diseases and increase environmental protection. While the financial returns to the investors may be substantially less than the social returns to the beneficiaries, it is usually in the best interest of governments to assume responsibility in facilitating or even sponsoring these forms of knowledge generation. This can be seen in the spectacular success of Cuba in managing their healthcare services and achieving some of the lowest mortality rates worldwide, easily comparable to many industrialized countries [WHO 2001].

2.1.3 Knowledge and innovation as drivers for economic development

The accumulation, transmission, application, and dissemination of knowledge are the keys to sustainable economic growth in the emerging global economy. Rapid advances in information and communication technologies (ICT) and declining costs of producing, processing and diffusing knowledge are transforming social and economic activities worldwide [Sung & Gibson, 2000].

While the knowledge revolution is resulting in many positive outcomes there is also the emerging concern of its fostering polarised societies and regions worldwide. On the one hand, scientific and technical advances have increased the economic welfare, health, education, and general living standards of a relatively small fraction of humankind to unmatched economic levels. On the other hand, the unevenness of such development among and within regions has increased. For example, 250 years ago, the difference in income per capita between the richest and poorest countries in the world was five to one; nowadays, the difference is more than 400 to one [Gibson, 1988, UNDP, 2005].

The reasons for these inequalities are complex and, according to most analysis, are to be found in the outcome of the social and economic revolutions that predate the current 'knowledge revolution'. The industrial revolution was driven by a lowering of costs in the distribution and processing of goods. This economic and social revolution generally divided the world into industrialised and non-industrialised nations that led to bi-modal societies.

The knowledge revolution is critically different from the past industrial revolution in that it is based upon a shift of wealth creating assets from physical things to intangible resources based on knowledge. The emergence of knowledge-based economic regions have traditionally been located near leading universities and research centres in the most economically advanced regions of the world [Gibson 1988, 1992]. Indeed, the importance of physical proximity of talent, technology, capital, and know-how or 'smart infrastructure' has been argued to be crucial to fostering wealth and job creation [Sedatis, 1997].

One of the effects of this knowledge revolution is the increased importance given to innovation and innovative activities. Innovation is achieved in many ways, with much attention now given to formal research and development for "breakthrough innovations." But innovations may be developed by less formal on-the-job modifications of practice, through exchange and combination of professional experience and by many other routes. The more radical and revolutionary innovations tend to stem from R&D, while more incremental innovations may emerge from practice - but there are many exceptions to each of these trends.

Another key source of innovation is user innovation, innovations developed by individuals when existing products do not meet their current needs. User innovators may become entrepreneurs, selling their product, or they may choose to freely reveal their innovations, using methods like open source. In such networks of innovation, the creativity of the users or communities of users can further develop technologies and their use.

Whether innovation is mainly supply-pushed (based on new technological possibilities) or demand-led (based on social needs and market requirements) has been a hotly debated topic. Similarly, what exactly drives innovation in organisations and economies remains an open question.

Joseph Schumpeter defined economic innovation in 1934:

- The introduction of a new good, or of a new quality of a good.
- The introduction of a new method of production, which need by no means be founded upon a discovery scientifically new, and can also exist in a new way of handling a commodity commercially.
- The opening of a new market, that is a market into which the particular branch of manufacture of the country in question has not previously entered, whether or not this market has existed before.
- The conquest of a new source of supply of raw materials or half-manufactured goods, again irrespective of whether this source already exists or whether it has first to be created.
- The carrying out of the new organisation of any industry, like the creation of a monopoly position or the breaking up of a monopoly position.

Regis Cabral defines innovation as a new element introduced in the network which changes, the costs of transactions between at least two actors or elements in the network [1998]. Amabile et al. [1996] defined innovation and its relation to creativity:

> *"All innovation begins with creative ideas...creativity by individuals and teams is a starting point for innovation; the first is necessary but not sufficient condition for the second".*

Creativity is seen as the basis for innovation and thus innovation is seen as the successful implementation of creative ideas within an organisation.

These different interpretations cause difficulties when studying innovation as a theory and setting the operational definition for the term 'innovation' for use in empirical research. The OECD Oslo Manual [1995] has emerged as the internationally recognised standard for measurement of innovation. Based on Schumpeter's first two criteria, the OECD defines Technological Innovation as:

> *Technological product and process (TPP) innovations comprise implemented technologically new products and processes and significant technological improvements in products and processes. A TPP innovation has been implemented if it has been introduced on the market (product innovation) or used within a production process (process innovation). TPP innovations involve a series of scientific, technological, organisational, financial and commercial activities. The TPP innovating firm is one that has implemented technologically new or significantly technologically improved products or processes during the period under review.*

Studies published on innovation on a national level tend to concentrate on measuring innovative activity (via their related expenditures) within firms, and in most cases these are conducted with statistical input and assistance from governments. One such study, which will be discussed in Chapter 4, is on the innovative activities on Malaysian manufacturing firms. Like many others, it follows the OECD definition of innovation, yet the only source of the data is statistics provided by the Ministry of Science, Technology and Innovation. This data would be more valid if it were compared with patent statistics or relevant academic studies; however it is considerably easier for governments to qualitatively measure activities rather than products or processes.

The different interpretations of innovation as a theory have been discussed, yet the confusion remains over the operational definition of innovation in the context of empirical research. Many national studies on innovation quote the OECD definition, which is the introduction of new and improved products or processes. This study will make use of the OECD definition due to its relevance to the body of data to be analysed, as well as its extensive usage in innovation surveys. However it would be important to note that the other aspects of innovation (creativity and ideas, taking risks) are difficult to quantify and as such there is no significant body of data other than 'innovative activities' to analyse.

The analysis provided by Conceição *et al.* [Conceição, Gibson, 1998] explains the difference between ideas and skills. These two kinds of knowledge differ in the way they are used, diffused, and produced. However, they are strongly interdependent in learning processes that lead to the accumulation of knowledge. The conceptual difference between ideas and skills lies in the level of codification. While ideas correspond to knowledge that can be articulated in words, symbols or other means of expression, skills cannot be formalised or codified and remain in tacit form. This apparently simple difference has very important consequences in terms of the way in which knowledge is produced, diffused and used.

The really substantial gains in wealth are to be found in the usage and diffusion of knowledge and innovation. Without skills, ideas may be irrelevant, and without ideas and creativity, there may be no need for new and better skills. The invention of writing (probably one of the most important ideas in the history of humankind) initially required the development of writing skills. Similarly, the widespread use of the computer is increasing the demand for computer literacy. New technologies spur the development of skills required to use these new technologies. In other words, the bridge from the production of ideas to the usage of ideas is established by producing new skills. Increased use of an idea will lead to a constellation of other ideas, aimed at improving and extending the initial idea, which will lead to the need for further skills and so on, in a self-reinforcing cycle that leads to the accumulation of knowledge.

History is full of examples in which the producers of ideas and skills, by not using and diffusing them, were surpassed by others that did use them even though they were not the initial innovators. Two examples, one at the grand scale of the history of civilisation, the other at the much smaller scale of contemporary corporate warfare, serve as illustrations.

China developed what was, after the invention of writing, one of the most important ideas for the progress of humankind, the movable type printing press, an idea that dramatically increased the possibilities of codifying knowledge. However, Imperial China restricted the use of this technology to the affairs of the Emperor and its court. Consequently, Europe capitalised on this invention by promoting its widespread use and diffusion [Landes, 1998]. A more contemporary example is provided by Xerox PARC, located in Sunnyvale, California, that invented many of the computer and software concepts and technologies that have become the basis of today's Windows operating system. Not even Apple, initially more successful than Xerox, was able to fully capitalise on the potential of wealth in this new knowledge. In the end, it was

Microsoft that reaped most of the potential technological benefits and financial rewards.

In conclusion, the accumulation of knowledge leads to the creation of wealth only if the knowledge is effectively transferred, adopted, and diffused.

2.2 Production of knowledge

2.2.1 The changing social contract

An interpretation of the changes underway in research and in universities is understood in terms of a changing 'social contract' between science and the university, on the one hand, and society and the state, on the other [Guston and Keniston, 1994a]. The original social contract, which ran from 1945 to the late 1980s (in the United States at least), is generally linked to Vannevar Bush and his 1945 presentation to President Franklin D. Roosevelt, *Science: The Endless Frontier* [Bush, 1945]. The report was influenced by the contributions of scientific discoveries of the first half of the 20^{th} century, especially supporting the military industry in World War II.

The emphasis of the report was on the application of a linear, 'science-pushed' model of innovation, beginning with basic research, leading to applied research, then technological development and finally innovation. The social contract for the post-war period could be described in the following terms:

> *Government promises to fund the basic science that peer reviewers find most worthy of support, and scientists*

> *promise that the research will be performed well and honestly and will provide a steady stream of discoveries that can be translated into new products, medicines, or weapons.*
>
> [Guston and Kenniston, 1994b]

It was implied that it was the responsibility of the government to fund the basic research end of the chain, and the results would eventually be beneficial in terms of wealth, health and national security. However, this led to criticism of the system in that the timeframe and exact form of benefits were unspecified and unpredictable.

One of the characteristics of the Bush social contract was that scientists and researchers were given considerable autonomy, with few strings attached to funding. It was perhaps due to this that during this period that the peer review system for allocating resources was institutionalized. Overall, the social contract was considered very successful from the time of its implementation, resulting in large increases in government funding, trained scientists and research outputs [Martin, 2003].

Guston points out the emergence of a revised social contract, beginning some time around the end of the 1980s, shifting away from basic research, towards a form of applied research based on the needs of society [2000]. In the case of the United States, that revised contract was described by Representative George Brown (for many years, a leading Congressional figure in US science policy) as follows:

> *The scientific community must seek to establish a new contract with policy makers based not on demands for autonomy and ever increasing funds, but on the implementation of an explicit research agenda rooted in [social] goals.*
>
> [Brown, 1992; Guston and Kenniston, 1994]

In other words, under the revised social contract there is a clear expectation that, in return for public funds, scientists and universities must address the needs of 'users' in the economy and society. Furthermore, they are subject to much more explicit accountability for the money they receive. In addition, implicit in the new contract is a much more complex model of innovation than the previous linear model, ironically making it much harder to persuade politicians of the merits of increasing public spending on research.

2.2.2 Shift from mode 1 to mode 2

Gibbons et al. [1994] provided an interesting analysis of the evolving and dynamic nature of knowledge production in universities. They argue that there is an apparent shift from what they label as "Mode 1" to "Mode 2" forms of knowledge production. According to them, Mode 1 refers to the traditional knowledge created in a disciplinary and cognitive context, reflecting the academic and scholarly research largely conducted by universities. This form of knowledge generation is said to have little connection to societal needs and the results of the research are transferred at the end of the project to users who may or may not take up those results. There is also fairly limited social accountability required from those engaged in research in terms of justifying the expenditure of the public funds used to support their work.

By contrast, Mode 2 represents knowledge created in broader multi-disciplinary social and economic contexts, with interaction between institutions and sectors. The knowledge created is produced "in the context of application"; usually in response to societal (and to a lesser extent scientific) needs, and by extension requires more social accountability for the funding received. Figure 2.1 below represents an overview of Mode 1 and 2 knowledge production, as summarized by Durrani and Forbes [2003]

Mode 1	Mode 2
Problems identified and solved in the context defined by largely academic interests of a specific community	Knowledge creation is driven by and carried out in a context of application
Disciplinary	Trans or Multi-disciplinary
Homogeneity	Heterogeneity
Hierarchical, and preserving of its organisational structure	Heterarchical and transient organisational form
Accountable within largely academic parameters	More socially accountable and reflexive

Fig. 2.1 – Gibbon's modes of knowledge production and their features [Durrani and Forbes, 2003]

This school of thought claims is that fundamental changes are now being observed in the ways in which scientific, social and cultural knowledge are produced.

> *[T]his trend marks a distinct shift towards a new mode of knowledge production which is replacing or reforming established institutions, disciplines, practices and policies.*
>
> [Gibbons et al, 1994]

But while Gibbons et al. are implying that Mode 2 is a new phenomenon, Weingart [1997] and Godin [1998] claim that evidence for such a conclusion is not convincing. It is perhaps better to characterise this not so much in terms of the appearance of something new in the form of Mode 2, but rather a shift in the balance between the already existing forms of Mode 1 and Mode 2. In other words, there has perhaps been relatively more Mode 2 taking place towards the end of the 20th Century than in previous decades.

2.2.3 The Triple Helix Model and the 'Third Mission'

Another significant and related characterisation of the nature of knowledge production and of universities was put forward by Etzkowitz and Leydesdorff [1997]. Their Triple Helix model, focused on the innovation system, consists of three institutional spheres and the interactions between them. Each of those institutional categories is called a helix (sometimes also referred to as a dynamic) to symbolize the 'spiralling' nature of the communication networks within and between them [O'Malley, 2002]. They suggest that the ever-increasing links between universities, government and industry can be defined in terms of a 'triple helix' model, as illustrated in Figure 2.2

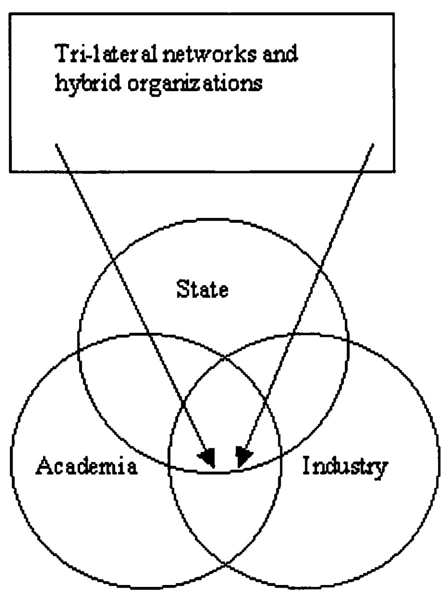


Fig. 2.2 The triple helix model of university-industry-government relations [Etzkowitz and Leydesdorff, 1997]

While the structure of their model is based on Pauling's suggestion to Watson and Crick's DNA structure solution [Judson, 1996], it in fact borrows heavily from

Luhmann's general theory of society [1982], which combines three 'independent and irreducible' general theories: systems theory, evolutionary theory, and communication theory.

In the Triple-Helix model, universities are seen as taking on a new third mission (in addition to the two traditional missions of teaching and research) of contributing to the economy. Etzkowitz states that the taking up of this third mission represents the 'second academic revolution', the first having been when primarily teaching institutions took on the role of research after World War II [Jencks and Riesman, 1968]. The result is the emergence of the 'entrepreneurial university', which combines teaching, research and contributing to the economy particularly in the local region [Etzkowitz, 1997; Etzkowitz et al., 2000; Clark, 1998].

However, questions have been raised as to the model's validity [O'Malley 2002] and what it adds conceptually [Shinn, 2000]. As with Gibbons' shift to Mode 2, there are also doubts as to whether this three-sided relationship and the 'third mission' of the university are entirely new. Indeed, academic entrepreneurship has been a keystone of the German chemical industry with its close relationship to academic researchers and the German system of apprenticeship [Gustin, 1975]. In addition, a 'demand-pull' model of knowledge transfer, in which universities are increasingly interacting with the wider society, has largely replaced the outdated 'supply-push' model that saw universities determine research priorities.

Third mission activities are concerned with the generation, use, application and exploitation of knowledge and other university capabilities outside academic environments, as defined by SPRU [Molas-Gallert, Salter et.al, 2002]. In other words, the third mission is about the interactions between universities and the rest of society. The analytical framework provided by SPRU starts with a basic distinction between the capabilities of universities and their activities.

Research universities have capabilities in two main areas, namely knowledge capabilities and physical facilities. These capabilities are developed as universities carry out their core functions of teaching and research. Using the means at their disposal, universities carry out three main sets of activities; they teach, research, and communicate the results of their work. All these activities can be considered third mission when they engage or target non-academic communities.

An acceptable understanding of third mission activity might embrace all of these, while recognising that this third mission is integrated with teaching and research. More emphasis is being placed on these third mission activities for the transfer of knowledge in order to create and benefit a knowledge-based economy. There is a general consensus of opinion that the universities could contribute more through more effective engagement with the industrial and commercial sectors. However, the means, mechanisms and motivations for this engagement are neither obvious nor agreed.

It is necessary to define the scope of the third mission activities carried out by universities for the purposes of this study. The present set of activities categorised as third mission range from assisting non-profit organisations and disadvantaged persons, to collaborations with governments to solve problems related to the national agenda set by governments, to outright sale of research findings. However, not all of these activities are related to the transfer of technology from universities to industry.

On the other hand, the measure of commercialised or licensed intellectual property alone will not show the fundamentals necessary for the transfer of technology to take place. For example, relevant government policies and assistance, and the relationships between members of academia and industry are important factors but these are not readily measurable as compared to the number of patents granted.

In the case of developing countries, especially where the numbers of patents are too small to make a significant study, more attention should be paid to the conditions for successful technology transfer. Therefore in this study, the scope of the third mission activities to be observed will be limited to the interaction between universities and industry in the form of collaborative research activities, consultancy services, training of industry personnel, as well as licensing of research outputs.

2.3 Science Policies for National Development in Developing Countries

2.3.1 The First Wave

Through the 1970s and 1980s science and technology policy provided a tool for developing countries in seeking economic independence, maintaining economic growth and increasing international competitiveness in global markets. International agencies were a driving force in steering national governments to adopt national

S&T plans as part of their overall national strategies. In the Asia Pacific, for example, UNESCO sponsored the first regional science policy and management conference in 1965. This event played an important role in generating national plans for science and technology for development. Subsequent S&T policy approaches that followed ranged from comprehensive government planned science to more *laissez-faire* "science-push" approaches or to the industry demand approaches characterised by Japan and the Republic of Korea [Hill *et al,* 1996]. Such strategies were strongly supported by agencies such as the World Bank and the Asia Development Bank. Indeed these agencies in many cases underwrote the cost of developing these plans.

The different social, cultural, industrial and historical experiences across the Asia Pacific led to quite different national approaches to S&T policy. Two common features, however, can be observed across most national plans. First, in almost all cases there was a strong focus on building an institutional base for steering and carrying out research. Secondly, the models and ideas that were adopted for developing the institutions were largely borrowed from the successful (and sometimes unsuccessful models) from Europe and North America. The practical implications of implementing these policies primarily concerned the task of managing these institutions.

Similar developments were experienced in Africa. During the 1970s, many African States were establishing national science institutions. Ministries for Science and technology were set up in Nigeria and Senegal. Ethiopia and Tanzania set up Commissions for Science and Technology, and Ghana, Mali and Sudan established

National Research Councils. As Adeboye has pointed out many of these institutions were set up in order to respond to quite specific needs, such as control of crop pests [1996]. Once established, however, they provided a central focus for broader scientific development.

In Asia, some national policies coincided with quite spectacular economic and scientific growth. The Republic of Korea, for example, maintained an average growth rate of over 8% throughout the 1980s. As an indicator of scientific growth the number of new Korean patents, registered in the United States each year rose from 26 in 1983 to 1486 in 1996. In other countries, the growth was more modest with 1.5% annual growth and little increase in their rate of patenting. In the Philippines GDP from 1980 to 1990 grew at just over 1% per annum and their patents registered in the United States remained, on average, at only 4 or 5 per year and with 6 registered in 1996. The figures for these nations were provided by the Penn World Table [Heston et. al., 2002].

While technological development contributed to economic growth in countries such as Japan, Korea, China and Taiwan, others such as Indonesia, Thailand and Vietnam made little headway in terms of comparative economic performance and development. Due to their low-cost labour intensive industry base for multinational corporations, they remained dependent on sustained growth and competitiveness among the former group of countries.

2.3.2 The Second Wave

By the 1990s, a second wave of science and technology policy was rippling across developing countries. This was flowing from a growing recognition that scientists, engineers and technological capability were locked into public sector institutions rather than distributing skills and expertise into the productive sectors. In the early 1990s in Indonesia, while public investments in science were increasing, only 33% of General Expenditure on Research and Development (GERD) was supported by industry, and much of that was carried by foreign internationals. In the Philippines, the figure was 23% and in Thailand was only 12% [Turpin et. al., 2002]. Not only were the outcomes of public sector research having little impact in the productive sectors but in addition, the public purse was finding it increasingly difficult to support the national core of science and technology capability.

In contrast, Korea during the same period, 84% of (GERD) was supported by the private sector; in Japan the figure was 67%, and in Singapore 63%. In Korea, average annual real growth in business sector R&D funding increased by over 30% per year between 1981 and 1993 [Turpin et. al., 2002]. S&T policies in developing economies through the 1990s sought similar outcomes and became more directly focused on diffusing science and technology capabilities out of the public sector. A report by the World Bank in 1996 on the Indonesian situation illustrates a general view that was increasingly influencing S&T policies in these countries through the mid 1990s.

> *The public technology institutions are under increasing pressure to become more market responsive and to have their research enhance the competitiveness of industry. Budget constraints on technology support institutions are partly a result of the global trend of fiscal austerity as well as disappointment with the value added generated by the*

> *institutions ...They lack systems to market their research to firms or to assess the R&D requirements of Industry. Many entrepreneurs are not even aware of the R&D capacity that exists within the institutes. Even when they are they are sceptical about its relevance to the technology development and competitiveness issues with which they are grappling*
>
> [Mans, 1996]

Institutional linkages and programmes to support the diffusion of technology characterised this second wave of policymaking. In Indonesia, long-term development plans through the late 1990s placed an unprecedented level of importance on programs to build closer links between public and private sector enterprises and promote innovation through research institutes and Technical Service Units (UPTs) [Mans, 1996]. The latter were specifically targeted toward raising technological capability among SMEs, particularly in small-scale industrial estates. S&T policy in Thailand sought to turn around comparatively small private sector investments in R&D and increase private sector technical skills development through a new skills development training scheme, through SME development programmes and enhancing financial incentives for technology upgrading in the private sector.

In China, the *863 High-tech research and development program*, started in 1996, targeted applied research for priority areas including: biotechnology; space technology, information, laser technology, automation, energy and advanced materials [Zhu, 2000]. This reflected a major shift from large-scale mission focused science investment to areas identified as priority for commercially oriented industrial production. This paralleled a program started in 1988 (*Torch Program*) to commercialise discoveries from institutes and universities and to create new technology enterprises [Turpin and Liu, 2000]. The Torch program was a key initiative in providing technological links for the establishment of 53 New High Technology Zones (NHTZ) across China. The Philippines targeted research centres as the best medium for improving industry- university linkages while S&T parks were identified as being the most important mechanisms for strengthening linkages.

Thus while science policy through the first wave was focused on building capability within S&T institutions, the second wave was more concerned with building collaboration between institutions and sectors. It was focused on harnessing institutions and capabilities to contribute to a national system of innovation. The task articulated in many government S&T policy reports was to manage the links between institutions and between different sets of activity.

Training, research and consulting previously seen as separate activities were becoming more intertwined through organisational alliances and practice. By the 1990s, almost all countries were reassessing their national S&T capabilities in the context of economic development in sub-sectors and regions of their economies. For science and technology policy, this represents a marked contrast to the efforts of the 1980s. The policy emphasis was on the social as well as the technical nature of innovation and building networks of 'actors' and 'agencies' to integrate science and markets [Krishna, 1994].

Through this more recent policy lens, science institutions are seen as only one of many sources of knowledge within a national system of innovation. Bringing S&T policy into a national system perspective meant that S&T could no longer be managed as a separate component of national development that needed to be formulated, implemented and evaluated in the context of contributions and capabilities of a variety of other agencies and institutions.

2.3.3 Change and Implications for Development

The underlying structural features and negotiated alliances between universities, governments and industry in what has been characterised as the second wave of S&T policies are consistent with what Leydesdorff and Etzkowitz identify as their Triple-Helix of knowledge production. The Triple Helix takes account of '...the expanding role of the knowledge sector in relation to the political and economic infrastructure of the larger society' [Leydesdorff and Etzkowitz, 1997]. More significantly, human agents or 'carriers' as they put it, become the key shapers of change as they forge new alliances and cross traditional scientific boundaries.

There is growing evidence of these alliances in what Ziman refers to as a 'new localism', where the culture of the marketplace has engendered complex webs of collaborative partnerships between universities and industrial enterprises. Ziman has proposed that the structural nature of this change is such that it now makes sense to refer to 'post academic science' [1994], and has since referred to the policy shift noted above as 'bringing science in out of the cold' [1995].

From another and perhaps more influential perspective, Gibbons et al [2002] propose that the shift toward Mode 2 knowledge production is happening, where the outcomes of investment in science are steered more by social expectations of accountability. Thus, a much broader range of actors and institutions are drawn into debates about what constitutes good science. The different domains of social activity clearly identified and separated by the first wave of S&T policy, discussed above, converge in Mode 2 knowledge production. As Nowotny *et al* point out: '...our argument was that science could no longer be regarded as an autonomous space clearly demarcated from the 'others' of society, culture and (more arguably) economy [Nowotny *et al*, 2001].

These perspectives have generated considerable debate about the implications they carry for science policy. But in most cases, discussion has focused on changes and challenges in industrially developed economies. For example, Gibbons *et al* [1994] draw attention to the need for governments to respond to these changes and create more 'permeable' institutional structures and become more "...proactive brokers in a knowledge production game which includes, in addition to the interests and ambitions of other nations, the policies of supranational institutions, such as the European Union". On the other hand, other observers have argued that the 'Mode 2' observations are simply a reflection of earlier observations about the relationships between science and society. However, there is very little debate about what these relationships mean for countries with only limited industrial capacity, with scarce financial resources, with limited human capital, and whose S&T institutions are almost entirely dependent on international funding. For these countries, their capacity for knowledge production transfer and transmission is dominated by international politics and the power plays of transnational enterprises.

In many developing countries in Africa and South East Asia, there is evidence that these global processes are eroding the capacity to accelerate the production and transfer of new knowledge to underpin development. However, there is also evidence that they are undermining the capacity to build or draw on local knowledge, embedded in existing modes and practices of production, that have driven development in the past. There is an irony that while the 'new production of knowledge' thesis implies a 'new localism' in knowledge production in industrially developed economies, the significance of local knowledge systems in driving development are generally overlooked.

A few observers, such as Krishna *et al* [2000] have emphasised the need for new S&T networking strategies in developing countries. They have expressed deep concern that the trend toward Mode 2 production will leave developing countries even more vulnerable than in the past. Developing countries are getting increasingly tangled, they note, in "... a double-bind situation in responding to the market forces under globalisation on one hand and in sustaining research activities directed to public good on the other " [Krishna et al, 2000].

Similarly, Vishvanathan has criticised Castells for taking the nature of modern science for granted and failing to recognise the 'politics' of knowledge and a politics of competing theories of knowledge' [Vishvanathan, 2001]. Vishvanathan argues, in contrast, that there is a need to incorporate in our cognitive system consideration of many forms of knowledge '... because all such knowledge contains incommensurable insights':

> *By being insensitive to the fate of different knowledges and their link to the livelihood, lifestyles and forms of life, Castells becomes a mere cheerleader of the latest form of research and development management as a model for wider politics.*
>
> [Vishvanathan, 2001]

Building links across knowledge systems is important because such links allow for the effective transmission of new knowledge and its adaptation and incorporation into local systems of production. Scholars of the sociology of science have argued for some time that science has always been local [Turnbull, 1994]. Gibbons et al's 'New Production of Knowledge' thesis can, to some extent, be interpreted simply as a revived recognition of this. However, the impact of globalisation is increasingly impinging on the capacity of many countries to derive national benefit from local knowledge systems: scientific or traditional; and tacit or codified.

2.4 Different approaches to university linkages

2.4.1 University-Industry-Government Relations

The globalisation of the configuration of university-industry-government relations can be considered as a result of various developments that have coincided with the interconnection between the laboratory of knowledge-production and users of research at various levels. This is exemplified by the rapid growth of university-industry centres in which firms and academic researchers jointly set priorities. Another example is technology transfer agencies within both universities and firms that negotiate with each other and move technologies in both directions. This is also illustrated in the emergence, spread and convergence of technological and communication paradigms such as the computer, mobile telephony, and the Internet.

Interaction itself has become more extensive among organizations, multi-layered, and therefore relatively more important than the elaboration of perspectives within the walls of one's own institution based on routines and tacit knowledge. Added to this is the consequent transition from vertical to lateral and multi-media modes of coordination, represented by the emergence of networks, on the one hand, and the pressure to shrink bureaucratic layers, on the other.

Over time, these developments have led to shifts in the political-economic relationships among university, industry, and government, moving them closer in some societies and distancing them in others. For example, in the USA, university, industry, and government are supposed to work more or less independently of each other. Nevertheless, government plays an increasingly more important role not only in providing a regulatory environment, but also in encouraging innovation. Academia, traditionally supposed to be apart from industry, is increasingly involved with industry, not only through consulting and contract research but also in forming companies from academic research [Etzkowitz *et al*, 2001].

Other societies, such as the Former Soviet Union, started from a model of the state controlling and incorporating industry and academia. Some European and many Latin American countries have also maintained aspects of this model. The state was expected to coordinate industry and academia toward a common development goal. For example, in Argentina, Sábato's triangle concept provided government with a rationale to coordinate university and industry in order to develop new technologies and industries [Sábato and Botana, 1968; Sábato, 1997].

Whether countries started from the model of the state incorporating industry and academia or a configuration in which they coexisted relatively separately, the different helices have recently been moving in a common direction to stimulate both competition and collaboration. There is movement toward a model where the three institutional spheres will overlap, with each sometimes taking the role of the others.

The necessity to restructure institutional relations is caused by the knowledge-intensity of the economic development. Institutional relations are restructured with reference to their innovative capacities. In the U.S., laws assisting start-up and the commercialisation of academic research, such as the Bayh-Dole Act [Shane, 2002] have been enacted even in the face of opposition from large firms. Organized knowledge production methods and control systems provide a medium of social coordination that adds to economic exchange and political decision-making with potentially synergetic interaction effects.

2.4.2 R&D, Knowledge Flows and Knowledge Production

The transfer and utilization of R&D findings and their conversion to innovations are critical to ensure that the economic benefits from scientific research are realized. But the conversion of research to innovation is not unidirectional as portrayed in the linear model of innovation. Instead, the innovation process is highly interactive with numerous feedbacks taking place. A successful innovation requires the coupling of both the technical and the economic, rather than being solely a matter of 'technology push' or 'market pull' [Walsh, 1984]. Such coupling, according to Mowery and Rosenberg [Mowery, 1989] implies close cooperation among many activities in the marketing, R&D and production functions.

This nexus among the various activities has important implications for the way in which R&D institutions and their activities are managed. The importance of managing the innovation process becomes all the more evident since, according to Macdonald [1986] the innovation process is essentially an information process and successful innovation is the product of a total information package to which R&D makes only a contribution. Information contributions from other participants in the innovation process are just as vital. This diversity of information inputs from various sources suggests that the engine of innovative activities does not all lie within the formal R&D laboratories alone but can also be located in the firm's larger internal and external environment, in its own production and marketing system and in its relations with its suppliers, distributors and customers. Case studies on partnerships in the agricultural sector [Hall et al, 2001] remind us that successful technological development is a very complex process and is often a product from the interplay of personal, professional and institutional relationships that change and evolve rapidly over time.

The importance of such relationships and the process by which research is converted into commercial innovation can also be represented in terms of knowledge flows. Innovation can be considered as a transformation process in which knowledge flows from various activities, including R&D, suppliers and customers are translated into a new or modified product or process. The transformation process is not automatic. Nor does it occur, as Spangenberg et al [Spangenberg, Kline 1990] argue, in a standard way. They put forward that factors such as organisational freedom in budgeting and resource allocation, communication and environment for the implementation of strategic decisions are critical to the transformation process.

Thus, how well these knowledge flows are organised and exploited and ultimately contribute value for the customer will determine the performance of the innovative or research activity.

The characterisation of the innovation process in terms of knowledge flows has important implications for the way activities such as R&D are organised as well as determining its potential impact and degree of utilisation of its findings. This perspective helps to focus on the importance of adopting management practices that enhance the transformation of knowledge flows from the idea generation stage to adoption by the end-user. In addition, regarding the research-performing organisation as a knowledge system makes it easier to focus on the pivotal role of management in the research utilisation process.

The output of a research activity - undertaken either by industry or by a public-funded organisation - is knowledge. This knowledge can be manifested in either a product, a process or a service. The success of the knowledge system, according to Wikstrom and Normann [Wikstrom 1994], will be decided by the way in which this knowledge is received by the end-users and the value that the knowledge represents for them. Knowledge that makes a big contribution to the customer's own value-creating process will have value for potential customers.

The alignment of knowledge being developed with that actually demanded by the end-user underscores the need for partnership. In addition, such partnerships can involve, besides the end-user, others such as suppliers, industry associations and other organisations. Such alliances mean that end-users, as Wikstrom and Normann assert, must be regarded as co-producers in the research organisation's task to create value. This 'value creating philosophy' as well as emphasis towards joint development must underpin research activities of universities and public research institutes [1994]. Additionally, partnerships with other organisations will also contribute towards providing resources to exploit ideas. Such co-operation is critical since no one organisation possesses skills across a wide range of disciplines.

This emphasis on co-operation is particularly relevant since as Gibbons *et al* [1994] argue their thesis on the emergence of Mode 2 knowledge production emerging with heterogeneity and organisational diversity. Linking these diverse sources of skills and sites of production would place a premium on developing partnerships and other forms of networking as expounded by Etzkowitz and Leydesdorff [2001] in their Triple Helix of university-government-industry relations. This new mode of knowledge production would require, according to its proponents, a new style of management where strategies designed to foster inter-linkages among institutions as well as enhancing the permeability of institutions, are accorded emphasis.

People are the fundamental assets of an organisation, more so, in the case of a knowledge generating institution. They are, as Wikstrom and Normann describe, bearers of the knowledge on which the organisation's competence is based, and without competent people able to handle this knowledge, 'even the most advanced artefact will be useless.' [Wikstrom, 1994]. Such a perspective underscores the important role of management in the acquisition of staff as well as ongoing efforts to enhance the skills of existing staff.

Raising expertise and skill development assume importance since, as Cohen [Cohen and Levinthal, 1989] has noted, the level of internal absorptive capacity will determine an organisation's capability to identify, assimilate and exploit knowledge from its external environment. These efforts at raising internal absorptive capabilities have characterised the successful technological build-up of Korean firms such as Samsung and Hyundai [Kim, 2002]. Acquisition of technological competency is not automatic. It is a product of conscious learning efforts. Such learning efforts take place at various levels including the individual, the group and the organisation as a whole [Prahalad, 1990]. It is then a challenge for management to enhance continuous learning at all levels through specific programmes/projects.

How well all these knowledge flows and alliances are organised will determine the success or otherwise of the research effort. At the heart of this organisation lies management. And, it is management's task to ensure that the resources available to the organisation in transforming these knowledge flows - people, infrastructure and funding - are welded together through the adoption of proper systems in enhancing, what Nonaka [1992] describes as, the knowledge creation process.

The perspective of an R&D organisation as a knowledge system provides us with new insights on the dynamics of the research utilisation process. Such a portrayal has broad ramifications on the way R&D is conducted as well as on its transfer to the end-user. Above all, it demonstrates that if R&D is to be successfully undertaken and make a significant contribution both at the organisational and national level, it must be steered by sound management practices and not left to serendipity.

2.5 Technology Transfer

2.5.1 Analysis of US Legislation

The Bayh-Dole and Stevenson-Wydler legislation was introduced in the United States to address the problem that a large number of potentially valuable inventions created by universities and private research institutions with public funds were not being commercialised [US Congress, 1980; Jolly, 1980]. This problem was attributed to the absence of a uniform policy governing the ownership of such inventions, and to the lack of incentives for institutions to actively pursue commercialisation, as there was no guarantee that they would be given exclusive rights to the technology. Furthermore, government funding agencies lacked the expertise and the ability to see the commercial potential of a new invention. In this regulatory environment, it was thought that the US was unable to develop its own inventions and potential products were lost to overseas developers. Consequently, the US was decreasing in competitiveness in comparison with other industrialised countries.

The primary aim of both the Bayh-Dole and Stevenson-Wydler legislation was to provide a clear and uniform system of managing IP rights in publicly funded institutions, which would in itself provide an incentive for improved technology transfer. The Bayh-Dole act gave the option to grant the title of inventions to the researchers over all inventions created using public funds in universities and other research institutions [US Congress, 1980]. Stevenson-Wydler applied to government agencies and imposed a duty on federal departments to transfer technology to State and local governments and the private sector, and established administrative structures to support this obligation [Jolly, 1980]. Bayh-Dole empowered federal agencies to license federally owned inventions and enacted a detailed licensing regime. Both Bayh-Dole and Stevenson-Wydler provided that royalties from commercialisation should be shared with the inventor to provide an incentive to create inventions for practical use.

A secondary aim of the legislation was to create an additional incentive to patent inventions by introducing the potential for the government to confiscate ownership of an invention if it was not patented within a certain period. Further, to curtail the potential abuse of monopoly power, the government was granted a non-exclusive license to use the invention for government purposes and retain "march-in rights" which can be exercised in the public interest.

The legislation also aimed to maximise the benefits of publicly funded research to the national economy by requiring that universities and private research institutions ensure that products of the invention would be manufactured substantially in the United States. Moreover, the legislation provides that universities and government agencies must endeavour to license inventions to small business in order to give small businesses an advantage over large businesses in the development and commercialisation of inventions created using public funds.

An examination into the effectiveness of Bayh-Dole shows that the most probable effect of the legislation is that it accelerated the trend in patenting by universities, by removing obstacles surrounding complicated patent ownership rights. It has been hypothesised that a longer-term effect of Bayh- Dole is that it may adversely affect the quality of university research by changing the research culture on knowledge spillovers, and engendering a more aggressive attitude towards IP rights [Mowery & Sampat, 2003; Garduno, 2004]. However, there is limited empirical evidence that the Bayh-Dole Act has lessened the quality of university research in this way, though these effects may be underway.

2.5.2 Effectiveness of US technology transfer

In a study of more than 1200 university, industry and government laboratories, Bozeman [2000] found that 23% of university laboratories view technology development as a major mission, compared to 51 % government labs. Whereas 70% of university laboratories view basic research as a major mission, 42% of government laboratories do.

The strongest predictor of technology transfer participation was having a diversity of research missions. Those who were narrowly focused, regardless of the nature of the focus, were less likely to be engaged in technology transfer than those laboratories with diverse, multiple missions. The number of licenses related chiefly to the size of the lab; getting technologies out the door was best explained in terms of the missions of the laboratories and the composition of their R&D. Market impact, was determined by research diversity and degree of commercial orientation of the lab [Bozeman 2000]. A summary of these differing paradigms of viewing research is provided in Figure 2.3.

	Market Failure	**Mission**	**Cooperative Technology**

Core Assumptions	1) Markets are the most efficient allocator of information and technology 2) Government laboratory role limited to market failures such as extensive externalities; high transaction costs; and information distortions. Small, mission domain, chiefly in defence. Universities provided basic research, in line with private sector under-supply due to market failure (inability to appropriate directly the results of basic research 3) Innovation flows from and to private sector, minimal university or government role.	1) The government role should be closely tied to authorize programmatic missions of agencies 2) Government R&D is limited to missions of agencies, but not confined to defence. University R&D supports traditional roles of land grant universities such as agricultural or engineering extension, manufacturing assistance and contract research for defence or energy research 3) Government should not compete with private sector in innovation and technology. But a government or university R&D role is a complement	1) Markets are not always the most efficient route to innovation and economic growth 2) Global economy requires more centralized planning and broader support for civilian technology development 3) Government laboratories and universities can play a role in developing technology, especially pre-competitive technology, for use in the private sector
Peak Influence	Highly influential during all periods	1945 - 1965; 1992 - present	1992 - 1994
Policy Examples	De-regulation; contraction of government roles; R&D tax credits; capital gains tax roll back. Little or no need for federal laboratories except in defence support	Creation of energy policy R&D, agricultural labs, and other such broad mission frameworks	Expansion of federal laboratory roles and university role in technology transfer and cooperative research and other technology-based economic development programs
Theoretical Roots	Neo-classical economics	Traditional liberal governance with broad definition of government role	Industrial policy theory, regional economic development theory

Fig. 2.3 - Three Competing Technology Paradigms [Bozeman, 2000]

Powell and Oven-Smith [1998] examined the role of intellectual property in the life sciences and the transformation of universities. They argue that there is an increasing blurring of the division of labour between industry and academia. One result is increased politicisation of government research funding and, particularly, a more intense competition among universities. After conducting extensive case studies of university and government laboratory R&D funded by the Department of Energy's Office of Science, Powell et. al concluded that scientific and technical human capital is an often neglected and invariably underestimated set of criteria for research and technology transfer effectiveness [1998].

Lynn et al. [1996] and Bidault and Fischer [1994] provide a strong argument for a network-based concept of effectiveness, in part because their research shows that the specific ongoing relations among networks of technology partners is generally more important than are market factors to transfer effectiveness. Henderson et al. [1998] supports this, suggesting that the observed increase in university patenting may reflect an increase in their "propensity to patent" and possibly an associated increase in the rate of knowledge transfer to the private sector rather than an increase in the output of "important" inventions.

This increase in universities' institutional commitment to patenting, in the form of new and expanded, would likely not have occurred if the impetus toward research that is more commercial and the change in federal law had not occurred. However, once created, these offices presumably facilitate the patent application process and thereby contribute to the increased patenting. Finally, increased industry funding is probably partially a response to universities' increased interest in applied research, but it, in turn, increases the resources for these activities and thereby also supports increased patenting.

The Bayh-Dole Act and the increase in industry funding had two distinct effects on university incentives. Both the incentive to perform research that could be expected to produce important commercial inventions, and the incentive to patent and license whatever commercial inventions were produced. Clearly, the Bayh-Dole Act has been a success with respect to the second of these incentive effects. Both the rate of patenting and the extent of licensing have increased dramatically. In contrast to the impact on the transfer of technology, however, the Act and the other related changes in federal law and institutional capability have not had a significant impact on the underlying rate of generation of commercially important inventions at universities.

It is likely that the bulk of the economic benefits of university research come from inventions in the private sector that build upon the scientific and engineering base created by university research, rather than from commercial inventions generated directly by universities.

> *...if commercial inventions are inherently only a secondary product of university research, then it makes sense for policy to seek to ensure that those inventions that do appear are transferred to the private sector, but not to hope to increase significantly the rate at which university research directly generates commercial inventions.*
>
> [Henderson et al. 1998]

2.5.3 Universities and the innovation process

According to Jacobsson [2002], universities may influence the innovation process and society by various mechanisms such as

- Scientific publications that expand not only the technological opportunity set of academic peers, but also industry
- Training of engineers, researchers and scientists

- Training of postgraduates with the essential provision of background knowledge, skills and personal networks;
- Participating in common informal networks, joint R&D projects, research funding and contract research with an associated sharing of explicit and tacit knowledge (gained through research and being members of national and international professional networks);
- Linking national firms to international networks and providing access to explicit and tacit knowledge from a wider range of sources;
- Development of instruments and engineering design tools;
- Spin-offs of technology-based firms.

There has been strong emphasis on training, tacit knowledge and indirect benefits, rather than codified information (or even products) as being the main output of academic research into industry [Pavitt 1991, 1998; Faulkner and Senker, 1994; Mansfield and Lee, 1996]. Pavitt notes that the implementation of policies on high priority for basic research that are directly and obviously applicable ignore the considerable indirect benefits across a broad range of scientific fields resulting from training and from unplanned discoveries. These policies neglect the fact that the application of basic research depends overwhelmingly on the size and persistence in investment in downstream activities by business firms. Pavitt goes on to describe dealing with deficiencies in business R&D by making research more relevant is "like pushing a piece of string "[1991].

Pavitt concludes that the results of basic research are rarely immediately applicable, and making them so increases their appropriability. In seeking potential application, firms learn how to combine the results of basic research with other firm-specific assets, and this cannot be imitated overnight [1991].

2.5.4 Generation of start-ups & scientific entrepreneurship

Successful commercialisation of academic research must depend on the active participation of the researchers who were the original creators of the knowledge to be commercialised [Siegel, Waldman and Link, 2003; Zucker et al., 1998; Audretcsch and Stephan, 1996]. Spillovers from university research are less likely to be geographically localized than privately funded research [Henderson et al. 1996].

Di Gregerio et al. [2003] examined the influence of the venture capital, commercial orientation, intellectual eminence, university policies to the frequency of technology licensing officers (TLO) start-up activity. One of their findings was that in the US, roughly 12 % of university-assigned inventions are transferred to the private sector through the founding of new organisations [AUTM, 1998]. They also realized that the availability of local venture capital was not a constraint on TLO start-up activity. Other sources of funds, such as angels, government agencies, and universities themselves may be more important in the early stages, and thus may be catalysts for new firm formation and economic development.

There is no net effect on the TLO start-up rate of the university's commercial orientation. A low inventor's share of royalties and a willingness to make equity investments in TLO start-up companies increase start-up activity. Universities that are more eminent have greater TLO start-up activity than other universities. This result is consistent with the argument that leading researchers found companies to earn rents on their intellectual capital (Zucker et al., 1998).

These policy tools are important because start-ups and established firm licensees differ in several important ways, including their tendency to contribute to local economic development, their tendency to generate significant income for universities, and their decisions toward knowledge disclosure and research norms. [Di Gregorio et al. 2003]

Many universities distribute a high percentage of royalties to inventors in order to encourage the reporting and exploitation of inventions: however, the results suggest that high distribution rates also serve as a disincentive to the creation of start-up firms. In addition, the effects of university-affiliated incubators and university venture capital funds are insignificant. (Ibid. 2003)

Goldfarb et al. (2003) argue that the American system, whereby intellectual property is commonly awarded to universities, is more effective in facilitating the commercialisation than the Swedish system in which rights are awarded directly to the inventor. When policies are top-down, the desire of universities to implement them may vary, especially, since these universities face conflicting incentives. This has in turn affected academics' incentives to pursue commercial opportunities.

Putting property rights in the hands of the inventor does not automatically create the best incentives for commercialisation. To facilitate involvement in commercialisation activities, not only must an academic inventor face strong incentives in the market for technology, but she must also not face strong disincentives in her university environment. The system works better when incentives are aligned.

2.5.5 University patenting

Patents vary tremendously in their importance, making it dangerous to draw conclusions about aggregate technology flows based on numbers of patents [Griliches, 1990]. Recent theorisation in this field has established that wherever sequential innovation takes place, an overly generous granting of patents and trend of strengthened IPR can strongly hinder the innovation process [Hunt, 1999b; Grandstrand, 2000].

As pointed in recent studies, it seems that most of the patents that the bigger firms have been registering are not meant to protect inventions. Instead, they are supposed to "hinder" virtual rivals, or create strong bargaining positions [Coriat and Orsi, 2002].

An in-depth analysis of experiences in the US and Sweden by Henrekson and Rosenberg [2001] suggests policy aimed at encouraging science-based entrepreneurship should focus on strengthening individual incentives form human capital investment and entrepreneurial behaviour both within universities and in business. Key policy areas include attractive tax rates on entrepreneurial income, a tax structure that is not overly progressive, reasonably deregulated labour markets, and a university system characterized by decentralisation and competition. [Henrekson et al, 2001].

2.6 Hungarian National Innovation System

2.6.1 Innovation Policies in Hungary

Hungary emerged from the communist period as one of the economically and technologically most advanced countries in Eastern Europe. In particular, it had built up considerable expertise in manufacturing, including several branches of engineering, and it conducted much R&D. There were also reasonably intensive trade links with Western Europe in comparison with other socialist countries in the region. Strict Soviet-style central planning was practised for a relatively brief period from 1948 until 1968, when the New Economic Mechanism introduced some degree of decentralisation in decision-making by replacing physical planning by indirect price-based planning [Hare, 1991].

Transition has brought about a number of crucial political and economic changes affecting the S&T system. A number of S&T policy documents have also been drafted. However, up until 2000 no systematic technology or innovation policies had been approved by the government, let alone implemented.

In 1995, OMFB drafted a policy document entitled "The Government's Concept for Technical Development", providing a vision and listing government tasks in both the short and long term. This document summarised the most common arguments levied against a more pro-active S&T policy, together with counter-arguments, in an attempt to convince politicians and government officials that the OECD and EU member-countries were not following an extreme "*laissez-faire*" ideology. Further inter-ministerial discussions were blocked by the Prime Minister's Office, and hence the document never reached the cabinet [Havas, 2002].

In 1996, a "Modernisation Programme" of the then government coalition was formulated, incorporating some elements and ideas from the aforementioned document [OMFB, 1995], but again there was no political will and support for an innovation policy. Given the drastic stabilisation programme launched in 1995 there were no extra funds available to promote R&D and innovation. In fact, public financing for R&D reached its lowest level ever in these two years (1995-96).

The government's next attempt at an R&D policy was set out in a document entitled "Science and Technology Policy — 2000" [OM, 2000]. This document was first approved by the Science and Technology Policy Council in March 2000, and then confirmed by a government decree in August 2000. Despite its title, it is mainly a science policy document identifying five "national R&D programmes" on:

- improving the quality of life (*i.e.* biomedical, pharmaceutical and related projects);
- information and communication technologies;
- environmental and materials research;
- agribusiness and biotechnology; and
- national heritage and contemporary social challenges.

Research, development and innovation is one of the seven programmes outlined in a recent national development strategy, the Széchenyi Plan, also launched in 2000

[GM, 2000]. Its chapter 4, entitled "Program for the Support of Research, Development and Innovation Programme", consists of three sub-programmes for:

- the five national R&D programmes mentioned above;
- 'the extension of existing R&D support schemes and promotion of the R&D institutional network';
- 'increasing the absorption capacity of the R&D institutional network'.

As it is not easy to understand even the Hungarian titles of the latter two sub-programmes, their official translation is used here. Their relatively short explanation suggests that the main aims are to strengthen the R&D institutes' capabilities as a pre-requisite to conducting the "national R&D programmes" and increasing the number of R&D personnel in both the public and private sectors.

The emphasis of these policies seem to be focussed towards building the capacity to cultivate innovation, or "the supply-side"; this can be seen in the Szechenyi plan which aims to "extend existing R&D support schemes and networks" and "increase the absorption capacity of the R&D institutional network" [GM, 2000]. While this is certainly commendable, perhaps more emphasis could be placed on the "demand" side, for instance the government could take a more proactive role in public procurement of R&D to solve problems related to the national agenda, or requiring suppliers to develop solutions that do not exist at the moment and thus require some element of R&D.

2.6.2 R&D Statistics for Hungary

R&D expenditures have dropped significantly since the late 1980s. Whereas 2.3 percent of GDP had been devoted to R&D in 1988, this ratio fell to 1.04 percent by 1992 and has remained at 0.7% from 1996 until 1999. Given that GDP only reached its 1989 level in 1999, it is indeed a dramatic drop (see Figure 2.4). To compare, EU countries on average spend around 2% of their GDP on R&D. This is already a huge difference, moreover, their GDP *per capita* is three times higher than the figure for Hungary.

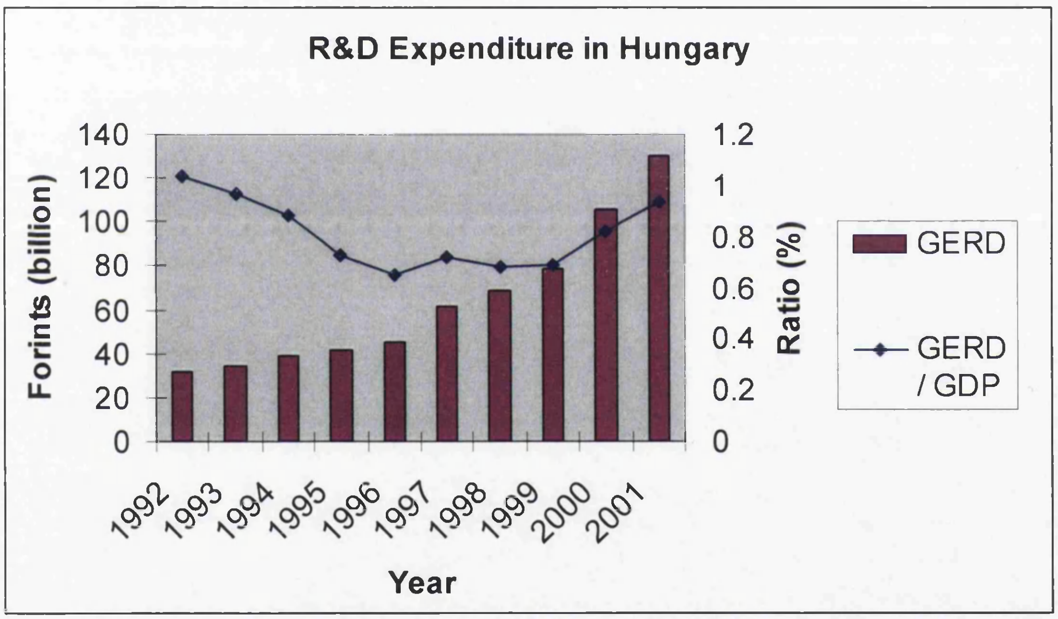


Figure 2.4 – R&D Expenditure in Hungary [HCSO, 2003]

In 2000 the Hungarian government declared that gross domestic expenditure on research and experimental development (GERD) should reach 1.5 percent of GDP by 2002. Although spending levels increased significantly since 1996, the GERD remained well below the mark in 2001, reaching only 0.94% of GDP.

The expenditure for R&D in Hungary was broken down by sector, and presented in Figure 2.5. There were sharp increases in R&D spending by industry in 1999 and 2001, and this was perhaps due to the end of the privatization era (around 1997) which reduced uncertainties that previously hindered innovative activities. The relatively low rate of growth for government expenditure did not follow the increase shown by industry, in fact there was minimal growth from 1998 to 2000. This was attributed by Havas [2002] to the reliance on European Union funding, specifically the Research, Technological Development and Demonstration (RTD) Framework Programme. In addition, universities were found to spend less on R&D compared to government and industry research initiatives.

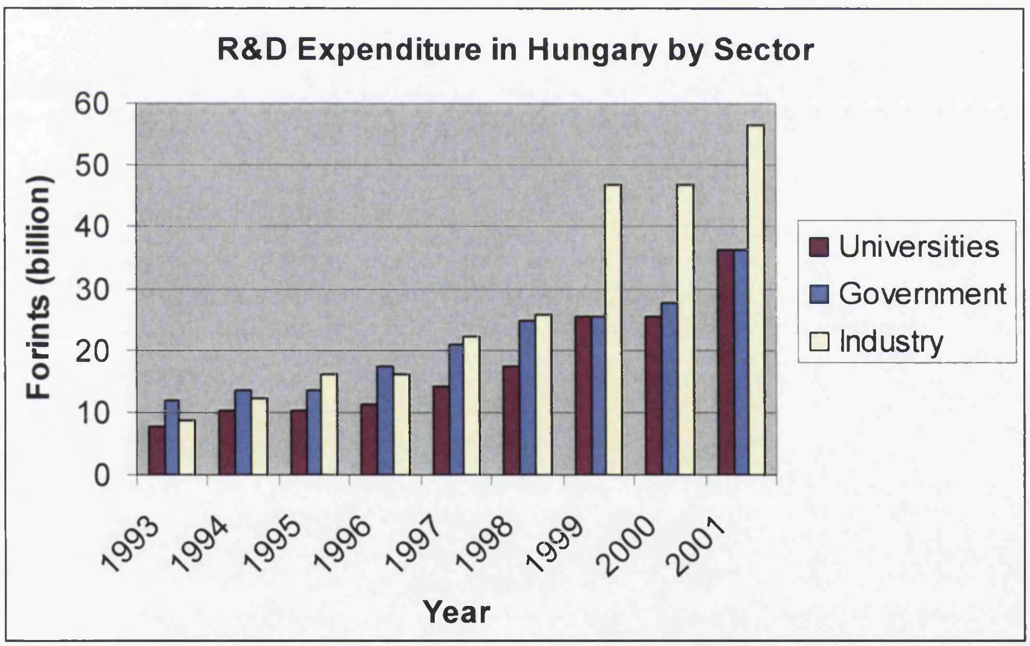


Figure 2.5 – R&D expenditure in Hungary by sector [HCSO, 2003]

The government remains the majority employer for full-time researchers, as shown in Figure 2.6 as well as the expenditure in R&D by the public sector. As with the decreasing in R&D spending, R&D personnel in industry were also cut drastically up until 1996. Since then, a steady increase can be observed.

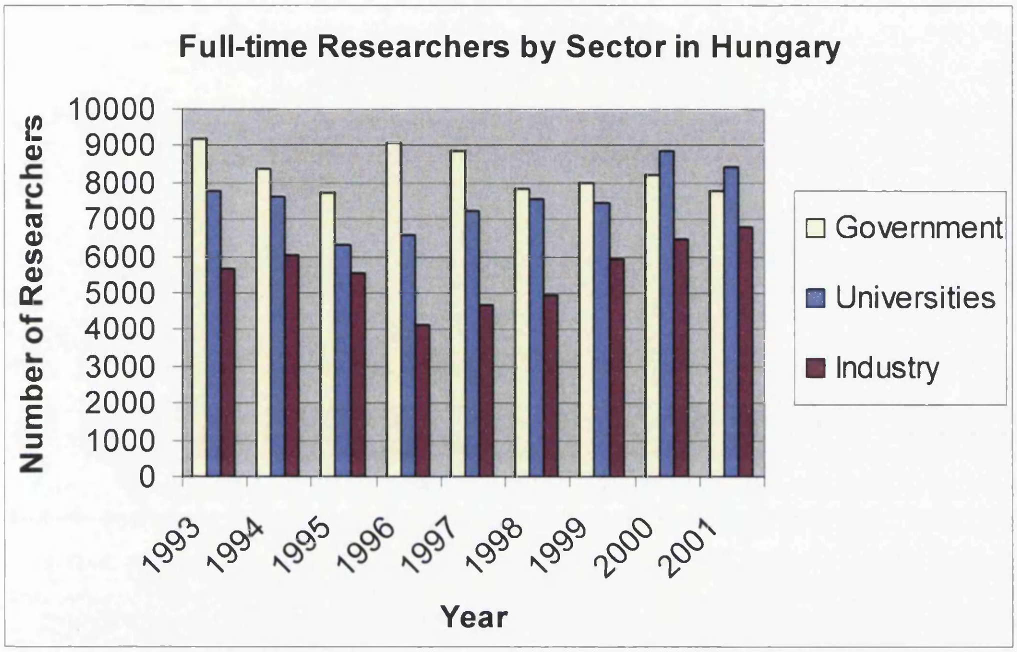


Figure 2.6 – Number of full-time researchers by sector in Hungary [HCSO, 2003]

In some cases, this cut in human resources involved necessary streamlining. In others, it implied a serious loss of useful knowledge (including tacit knowledge) and skills developed and accumulated over time. Clearly, it would not be possible to reproduce these intangible assets immediately when funds are increased. No reliable estimates are readily available on the share of necessary streamlining and severe loss. The large differences in the numbers of government and industry researchers in 1996 and 1997 can perhaps be explained by researchers seeking new and stable jobs in the public sector after being dismissed as a result of these streamlining exercises.

In order to obtain an indication on the state of the Hungarian national innovation system, the number of patents granted to Hungarians locally and abroad were analysed (see Figure 2.7). The numbers show that there is substantial activity amongst Hungarian researchers to apply for protection on their intellectual property abroad, especially considering the small domestic market.

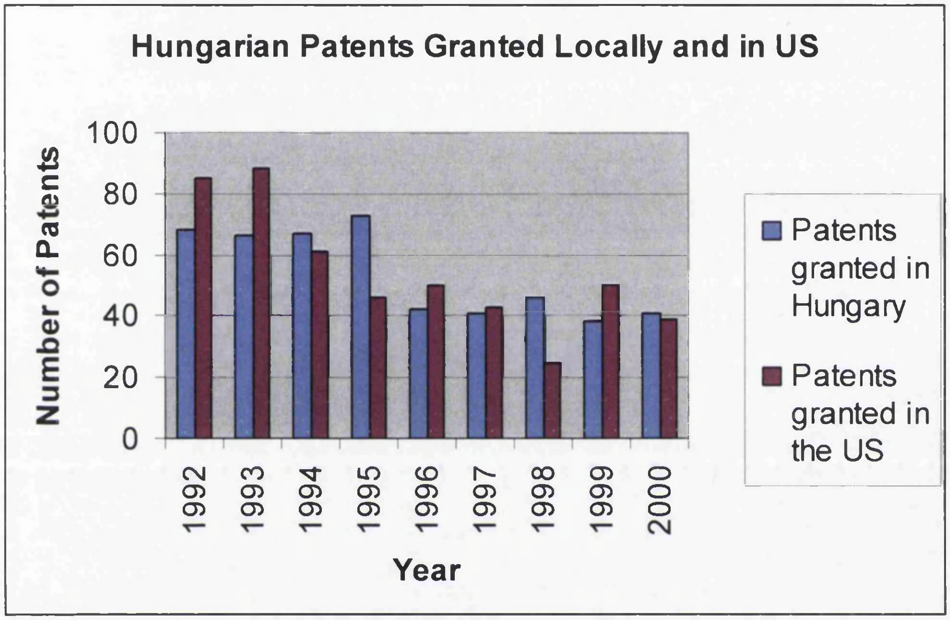


Figure 2.7 – Hungarian Patents granted in Hungary and in the United States [HPO, 2003; USPTO 2004]

The numbers of patents granted show a clear relationship with the GERD/GDP ratio shown in Figure 2.4. From 1992 to 1996, the ratio of GERD/GDP fell and the number of patents granted in the US, declined in a similar fashion. For the same period, the number of patents granted in Hungary remained below 70 and increased slightly in 1995, before declining in 1996 along with the drop in expenditure. Hungarian patents granted both locally and in the US remained at about the same levels from that period onwards (except for a sharp decrease in US patents in 1998). While the number of Hungarian researchers employed increased yearly from 2000, this was not reflected in the number of patents granted. This shows that the numbers of patents granted have a strong correlation with research expenditure levels.

The other measure of R&D outputs to be measured is the high-tech manufacturing sector and its share of total exports, presented in Figure 2.8. The value of high-tech exports maintained an average of 240 billion Forints from 1992 until 1996. As with the rest of Hungary's economy, the high-tech sector began to pick up pace and increased in value gradually from 257 billion Forints in 1996 to 2207 billion Forints in 2002.

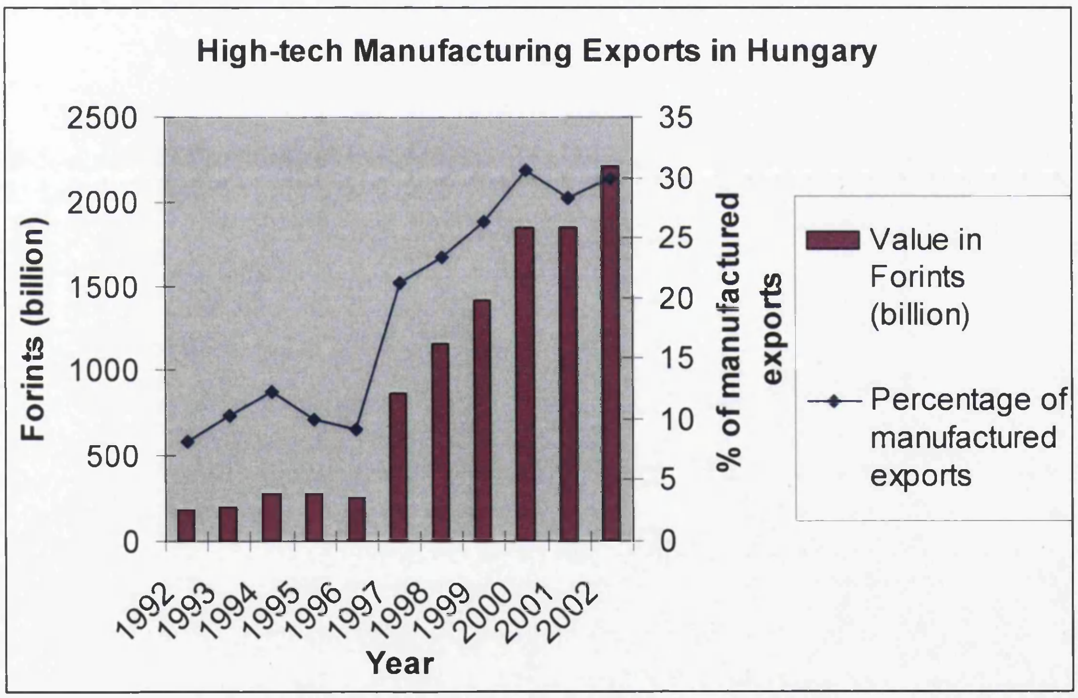


Figure 2.8 – Value and percentage of high-tech manufacturing exports in Hungary [OECD, 2004]

The contribution of the high-tech manufacturing sector to Hungary's total exports showed a similar trend, with an average of 10% from 1992 to 1996 and rapid growth from 1996 to 2000. The likely cause for the increase in exports would probably be the end of privatisation when firms began to respond to external pressures after complting their restructuring phase. Specifically, this increase in growth from 1996 onwards was led by the pharmaceutical and automotive sectors, which are traditionally dominant Hungarian exporters [Romijn, 1998]. The share of exports after 2000 shows strong potential, when compared to the OECD average of 20% [OECD, 2004].

3.0 CHAPTER III – RESEARCH DESIGN

Given the limited resources available to the researcher as well as the scarcity of available data on the commercialisation of research outputs from Malaysian public universities to the private sector, the design of the research had to be given careful consideration. This chapter will begin with a rationalisation of the choices made in the process of gathering data, within the context of studies on national innovation systems. The methods of primary data collection, which included interview questionnaires, visits and observations, will be discussed. Similarly, secondary data collection methods such as policy papers, internal documents and international economic reports will be highlighted to strengthen the validity of the methodology.

3.1 Research Methodology

The review of literature related to the topic highlighted two main trends in the approach taken for similar studies, namely policy-oriented studies and analytical models for comparative studies. In the case of Malaysia, it was found that there is a significant lack of literature and statistics on technology transfer, although there has been slightly more research published concerning the Malaysian national innovation system in general. In addition, a preliminary study concluded that present statistical evidence was insufficient to generate meaningful and comparative results.

However, there has been a recent increase in the studies of national innovation systems of developing countries, transformation economies in Eastern Europe as well as newly industrialized countries in Asia [Balzat and Hanusch, 2002]. As illustrated in Fig. 3.1, these studies, basically on low and middle-income economies, differ from the main body of literature on highly industrialized economies by highlighting the important differences between national innovation systems. One example is Wong's study on the Asian "tiger" economies of Korea, Taiwan and Singapore [1999], where the revelation of distinctive nuances in each country disputes the popular notion of a common success factor between them. Another similar facet of NIS studies on low and middle-income countries is to point out the different development stages and the timeframe and context in which these stages were reached.

Performance comparisons	**Studies of low and middle income countries**
Efforts to give the concept of NIS an operational dimension	Analysis of the development stage on the national system of innovation
Performance measurement / "efficiency" measurement of NIS	Verification of the relevance of the NIS concept
Methods: • use of innovation indicators • analytical models • calculation of index numbers (ranking of the systems analyzed)	Methods: • detailed verbal descriptions • use of innovation indicators
Negligence of historically grown • innovation patterns • institutional frameworks	Emphasis on historically grown • innovation patterns • institutional frameworks

Fig. 3.1 – Trends in the research on national innovation systems [Balzat and Hanusch, 2002]

It was therefore decided to begin the thesis with the approaches taken in these recent studies on newly industrialized countries in mind. This required the research to have an emphasis on gathering qualitative data, although quantitative data was also utilized to give an initial indication of the state of innovation in Malaysia, and to complement the findings.

In the earlier stages of the planning of the research, it was important to decide if the thesis should be in the form of a case study. To structure the thesis as a case study, it would necessitate studying the characteristics of a single unit – in this case, a particular Malaysian public university – and analysing the phenomena inside and around it, with a view to establishing generalisations about the wider context and population to which that unit belongs – in this case the Malaysian national innovation system.

While the data generated from case studies generally tends to be more valid and accessible [Cohen & Manion, 1995], the very nature of a national innovation system means that the connections and interactions between various actors, variables and outcomes are quite complex and difficult to compartmentalize and contextualize. It was mainly due to this and geographical and economical factors, that influenced this researcher not to conduct the research in the form of a case study.

3.2 Primary Data Collection Methods

The approach and methods of the research had to be planned to meet the aims of the research, which was essentially to present an indication of the state of the linkages within the Malaysian national innovation system, with a focus on technology transfer from Malaysian universities.

3.2.1 Semi-structured interview questionnaires

To gain an insight on the perceptions and experiences of researchers with respect to technology transfer, the thesis made use of semi-structured interview questionnaires. The semi-structured interview was chosen as a data collection method to enable the researcher to extract opinions, attitudes, values and beliefs from questions answered by the interviewee. In a semi-structured interview, a list of options can be provided from which the respondent can choose to guide the interview process. This differs from a more structured interview, where the categories or topics in which information is gathered are already determined.

The questionnaires were initially designed in collaboration with the Knowledge Economy Research Group at the University of Wales Swansea, to be part of a larger body of work intended to compare selected national innovation systems worldwide. Initial testing revealed the questions to be satisfactory in meeting the aims of the research, and the questionnaires were subsequently brought to Malaysia to be administered (refer to Appendix 1 for the pilot version of the questionnaire).

However, the results from the pilot research concluded that major changes were required for the questionnaires to be used effectively in a Malaysian setting. The main problem was that the questionnaires were targeted at respondents who were familiar with the process of technology transfer, with an emphasis on licensing technologies to industry. For example, questions were asked as to the number and frequency of successful technologies licensed by the respondent, where in the case of

Malaysia it was found that most respondents had barely any experience at all in taking their research anywhere near industry.

The questionnaire was then revised, mainly to generate a broader and less in-depth view of collaborative activities with industry (see Appendix 2 for the final version of the questionnaire). Another major change was the introduction of a section on intellectual property, reflecting another finding of the pilot research where it was unclear as to whether or not respondents were actually aware of the importance of intellectual property rights and protection with respect to their research findings.

The next stage was to identify research practitioners, ideally those with sound research findings that were ready for commercialisation. It was decided that the interviews and questionnaires were to be conducted where there were a significant gathering of researchers and support staff, to minimize travelling to different universities and institutions, as well as cutting down costs. At the time the research was conducted in Malaysia, it was interesting to note a rise in the number of events being held which were related to innovation and university-industry collaborations. This in itself was an illuminating indicator of the increasing importance given to strengthening the NIS.

Therefore, the questionnaires were distributed during research fairs and exhibitions, as it was assumed that the researchers present during these events had demonstrated that their findings were relevant enough to be exhibited to the public, as most of them had won awards and medals in international invention exhibitions. In fact, one of the objectives of such research fairs and exhibitions is to encourage industry to learn more about the research currently performed in universities and thus encourage collaboration.

The questionnaire began with a demographic profile of the respondents, which included their designation within their institution, details of their faculty or department and their academic qualification. This was to establish whether certain institutions were more active in technology transfer activities and also to find out if their position within the university allowed them more to be more active in such activities.

The profile of the respondents also included a section on their current research project, which would give details on the size of the research project team and the area of research. The classifications for the research areas were taken from the OECD Oslo manual for collecting technical data [1997]. Other details collected in the profile were the source of funding, the duration of research and the purpose of research output. The respondents were also asked to list down any forms of intellectual property protection that they had applied for.

The first section of the questionnaire was on the research activities performed within the university, with a focus on collaboration with industry. The respondents were requested to describe their involvement in university-industry collaborative efforts, from contract-based research and consultancy to licensing their research output. The management of research activity by the university was also examined, as well as the universities' capability to attract industry to take up research outputs.

As the main source of funding was expected to be federal funding in the form of IRPA research grants (Intensification for Research in Priority Areas programme managed by the Ministry of Science, Technology and Innovation or MOSTI), the respondents were asked to state any difficulties faced when applying for IRPA funding.

The second section of the questionnaire was designed to examine the respondents' knowledge and experience of identifying and protecting their intellectual property. The respondents were asked on their awareness of IP policies, laws and regulations in Malaysia and within their institution. The key points to be surveyed were if the respondents were aware of the department or personnel to contact within their organisation for IP related matters, as well as the government policy on distribution of income from commercialised IP assets.

The respondents were also to give their feedback on government intervention through legislature on the patenting of intellectual property generated from publicly funded research. The questionnaire ended with the respondents expected to state the way that they had personally benefited by taking advantage of their IP rights.

The questions were a mixture of open-ended questions, multiple choice, straightforward quantitative questions, and rankings based on the Likert scale [Likert, 1932]. The Likert scale is a set of attitude statements where subjects are asked to express agreement or disagreement of a five-point scale. Each degree of agreement is given a numerical value from one to five, for example a question using a Likert Scale might pose a statement and ask the respondent whether they Strongly Agree (1) - Agree (2) - Undecided (3) - Disagree (4) or Strongly Disagree (5).

The researcher administered the questions, in that the responses to the questions were recorded by the researcher on the questionnaire form as compared to the interviewees filling the responses in themselves. The main advantage of this was that the researcher was able to clarify or in some cases translate the questions for the interviewees, as well as ensuring the completion and gather rate of the questionnaires. However, this method also proved to be more time-consuming, and significantly reduced the number of subjects to be interviewed within a specific timeframe. While the respondents were more favourable towards the questionnaire as compared to the pilot study, there were some difficulties in answering questions particularly the ones that were open-ended.

The main limitation to the study was the selection of the samples for questionnaires. The researcher managed to conduct interviews with 62 interviewees, however only 42 questionnaires could be considered for data analysis, as some of the respondents were not able to give full answers to all of the questions, and in a few cases the academics who were interviewed had not performed substantial research of their own to justify their selection.

The sampling might be considered not representative of the researchers, as well as focussing on a narrow selection of researchers (i.e. present at exhibitions, and with established research findings). Another issue was the unwillingness or inability of a few respondents to answer particular questions, especially related to research funding, the reason being either they would rather keep it confidential or they were not privy to such information.

Below is a list of conferences, seminars, and research exhibitions that the researcher attended during the course of conducting this. These events proved invaluable as they brought together some of the top or lead researchers in the country as well as other serious-minded researchers. The exhibits, seminars and forum held during these events also provided significant sources of primary data:

- *National Conference on Intellectual Property and Related Rights,* Kuala Lumpur, September 2003
- *Biotech Initiatives in California: Bringing Ideas to Market,* Technology Park Malaysia, Kuala Lumpur, July 2004
- *4th Science, Technology & Innovation Exposition,* Kuala Lumpur, August 2004
- *Biotechnology Asia 2004 International Conference and Exhibition,* Kuala Lumpur, September 2004
- *National Intellectual Property Conference : Intellectual Property and the Innovators,* Ipoh, Perak, September 2004
- *Seminar on Advanced Management Practices and Human Resources Development for Sustainability of Research Institutions,* Kuala Lumpur, October 2004
- *IDD 2004 Intellectual Property Seminar,* Universiti Teknologi MARA, Shah Alam, December 2004

3.2.2 Experience interviews

Another approach to gathering data was the use of experience interviews, which were more focussed, non-structured and informal. These were conducted with policymakers, university research administration, experienced lead researchers as well as venture capitalists. The experience interviews proved invaluable in providing an in-depth perspective into the actual process of interaction and collaboration between individuals within their institutions and organisations in the process of technology transfer. This method was chosen to balance and complement the findings from the questionnaires.

One of the problems faced while conducting these interviews was that they were rather unpredictable, with the direction mainly coming from the interviewees' answers to previous questions. However, the interviewees were generally helpful and willing to answer questions to the best of their ability.

3.2.3 Visits and Observations

The research made use of actual visits to universities, government agencies and ministries, and technology incubators. Significant observations were made on the activities performed, and the way they were conducted, in these institutions, and in some cases, the researcher was privileged to join in meetings and observe first hand, the decision-making process. It would be relevant to note that there was a conscious effort made by the author to stand back and not influence activities during these observations.

One of the side effects of these visits was that valuable contacts were made with individuals within these organisations and institutions. Given the relatively small Malaysian public research sector, opportunities inevitably arose where these individuals were present during other events and as a result, more contacts were established with the net result of better access to data and interviewees.

3.3 Secondary Data Collection Methods

A review of relevant literature based on the research questions and which contextualizes this analysis, is presented in Chapter II. The following is a review on sources for secondary local data collection relevant to the research topic. Secondary sources provided invaluable information for this study.

3.3.1 Government policy papers and documents

The Malaysian government has proved it is committed to working towards a knowledge-based economy, and the K-Economy Master Plan [ISIS 1999] demonstrates this commitment perfectly. There is a wealth of official government literature on Malaysian S&T policy, and it was obvious that governmental policy papers and documents would be a main source for secondary data. It is to the credit of the government that their policy papers are readily available on government websites in English and *Bahasa Malaysia*, (the Malay language), even though internet and broadband penetration is poor in Malaysia. On occasion, the researcher was granted access to internal policy papers, for example ministry guidelines on selecting research projects for public funding and unpublished surveys on research commercialisation.

3.3.2 University documents

Another source of secondary data came from university internal policy papers and circulars. As with visits to government ministries, it was during the course of visits and observations to universities that the author was allowed access to private internal documents, for example intellectual property policies and draft contracts for research collaboration. University circulars also proved to be useful sources of information regarding research activities and potential candidates for commercialisation.

3.3.3 International Economic Reports

The study made use of statistics from two reports on global economic competitiveness, the World Competitiveness Yearbook 2004 and the Global Competitiveness Report 2003.

The World Competitiveness Yearbook 2004 was published by the Institute of Management and Development, based in Switzerland [IMD, 2004]. Initially, one of the proposed objectives to the study was to utilize statistics from the WCY 2004 report in a statistical model [Hwang, 2002] to determine the innovative capacity of Malaysia. However, the statistics for Malaysia provided by the report were unsuitable for the model, and did not justify the selection of the model for further analysis.

The Global Competitiveness Report 2003 was published by the World Economic Forum, and was the second report in that series to feature an analysis on the national innovative capacity model made popular by Porter and Stern [WEF, 2003].

While the bulk of data from these two reports predictably focus on traditional economic factors, the concept of national innovation systems was important enough to warrant separate sections and relevant statistics, which are appropriate to the study in terms of sampling and validity.

3.3.4 Other sources

Finally, the study also made use of other sources to supplement the secondary data collection. These included conference proceedings, press articles, and published academic and non-academic literature from journals, R&D periodicals, newspapers and in-house publications of various institutions.

4.0 CHAPTER IV – THE MALAYSIAN NATIONAL INNOVATION SYSTEM

In the two previous chapters, the concept of a national innovation system (NIS) was discussed. This chapter will present a review of the Malaysian NIS in the context of commercialisation of research outputs from public universities to industry. The review begins by describing national policies relevant to innovation in science and technology. Next, the government ministries and agencies involved in the research commercialisation process will be highlighted and their roles discussed. Secondary data in the form of statistics on public sector research, as well as private sector innovation will be presented. The review then discusses local technology parks and incubators, before concluding with an assessment of the Malaysian intellectual property regime.

4.1 Policies for Innovation

The political stability that has been afforded to Malaysia has been a fundamental cornerstone in the country's rapid development, characterized by strong leadership in implementing top-down policies. This can be seen in the various science and technology policies and initiatives which focus on promoting value-added research activities, strengthening linkages and enhancing productivity, all of which are intended to contribute to increasing competitiveness and sustainability. Ultimately, the goal is for Malaysia to achieve developed nation status by the year 2020, popularly dubbed "Vision 2020".

4.1.1 Third Outline Perspective Plan (2001 – 2010)

While macroeconomic developmental planning in Malaysia has always been driven by the five year Malaysia Plans, in this situation it is important to look at the bigger context in which the first steps towards a knowledge-based economy were taken. The Third Outline Perspective Plan (OPP3) was tabled in April 2001 by the Economic Planning Unit of the Prime Minister's Department to introduce policies and directions for economic development from 2001 to 2010.

Malaysia's comparative advantage in traditional manufacturing was being challenged by more dynamic lower-cost developing countries, while industrialised countries were forging ahead with their focus on knowledge and ICT. This, with the effects of globalisation and liberalisation, necessitated a shift from input-driven to productivity-driven mode, and therefore a recurring theme in the OPP3 was the enhancement of total factor productivity.

It was in the OPP3 that Malaysia began to assess her readiness towards becoming a knowledge-based economy, through a Knowledge-Based Economy Development Index (KDI). The KDI was derived from selected key factors required to drive a knowledge-based economy, which were found to be computer infrastructure, infostructure, education and training as well as R&D and technology. From this, Malaysia's position was ranked 17th, relative to 21 mainly developed countries (see Figure 4.1).

Country	Knowledge Index	Computer Infrastructure	Infostructure	Education and Training	R&D and Technology
USA	1	1	10	8	3
Japan	2	8	3	10	1
Sweden	3	5	2	3	2
Finland	4	2	4	4	4
Australia	7	6	6	6	11
UK	11	9	8	11	14
Germany	12	12	13	12	7
South Korea	15	16	11	16	13
Singapore	16	14	16	19	6
Malaysia	17	17	17	17	16
China	19	18	18	18	20

Fig. 4.1 – Knowledge-based Economy Development Index (KDI) [EPU, 2001a]

It was found that Malaysia was relatively well placed in terms of computer infrastructure, infostructure as well as education and training, perhaps due to Malaysia's large exports of electronic and electrical goods [EPU, 2001a]. However, there is significant room for improvement in R&D capability, computer usage, Internet connectivity and higher education enrolment. It was therefore decided that the thrusts of the OPP3 would be directed towards

- Developing a S&T manpower base;
- accelerating the development of infostructure;
- restructuring the financial system to provide appropriate types of financing for knowledge activities;
- reinventing the public sector to become more proficient and prepared for a knowledge-based economy; and
- taking affirmative action to bridge the digital divide between income, ethnic and age groups, urban and rural communities, and across regions.

4.1.2 Eighth Malaysia Plan (2001 – 2005)

The Eighth Malaysia Plan (8MP) [EPU, 2001b], the most recent in a series of five-year development plans, was one of the most prominent frameworks upon which Malaysia's thrust towards a knowledge-based economy was introduced to the public. This was an effort by the nation's policymakers to recognize that scientific advances and technological changes are becoming increasingly important in developing a knowledge-based economy, and hence to give emphasis on supporting S&T development which promoted productivity-driven growth and provided for competitive advantage.

With regards to the S&T sector, the 8MP aims to facilitate and further enhance the collaboration of the public and private sectors in R&D activities. This is achieved by restructuring existing R&D institutions to undertake more market-oriented activities; promoting technology applications in industry, expanding and strengthening S&T manpower; as well as creating new institutions to expand the R&D base and capacity, particularly in new and emerging areas.

In the effort to adopt an integrated approach to effective utilisation of R&D resources, public sector funding will be directed to focus more on research with potential for commercialisation. This involves realignment and fine-tuning of existing funding mechanisms, and provisions for prototypes and pilot-scale testing, which are usually not included in the scope of federally funded university research.

The private sector will also be considered within the national innovation system, with reviews being conducted on existing grant schemes and incentives. There is also added emphasis on acquisition of technology and intellectual property, not limited to locally developed technologies, which is a logical shift from Malaysia's previous phase of foreign direct investment to technology acquisition and absorption.

The federal government development allocation and expenditure for the period 1996-2000 and allocation for the period 2001-2005, demonstrates the commitment Malaysia has towards increasing S&T capacity and capability. The government will increase the funding for R&D and commercialisation of technology to RM 1.6 billion ($420 million), while RM 2.8 billion ($740 million) will be provided for related infrastructure facilities and services. Figure 4.2 presents a breakdown of federal allocation of funds for the development of S&T capacity.

Programme	7MP		8MP
	Allocation (RM million)	Expenditure (RM million)	Allocation (RM million)
Intensification of Research in Priority Areas	755.0	718.1	1000.0
Malaysia - MIT Biotechnology Partnership	35.0	33.3	-
Technology Development for SMIs	58.0	41.2	30.0
Technology Acquisition Fund (TAF)	118.0	118.0	250.0
Commercialisation of Technology	208.0	203.9	610.0
Industrial R&D Grant Scheme (IGS)	50.0	45.9	200.0
MSC R&D Grant Scheme (MGS)	65.0	65.0	200.0
Demonstrator Applications Grant Scheme (DAGS)	30.0	30.0	100.0
Commercialisation of R&D Fund (CRDF)	63.0	63.0	110.0
S&T Infrastructure and Development	2413.3	1496.7	2818.9
Total (in RM million))	3587.3	2611.2	4708.9

Fig. 4.2 – Malaysian federal allocation for S&T development, 1996-2005 [EPU, 2001b]

The Knowledge-Based Economy Development Index (KDI), introduced in the OPP3 was revisited in a mid-term review of the 8MP, published in 2003 [EPU, 2003].

Malaysia remained at the 17th position, still ahead of the competitive regional economies (refer to Figure 4.3, with 2001 figures in brackets).

In terms of the areas covered, Malaysia's ranking improved for education and training, was unchanged for computer infrastructure and infostructure, and declined for R&D and technology. Improvement in education and training was mainly attributed to higher current public expenditure on education as well as better literacy rate, pupil-teacher ratio in primary schools and enrolment in secondary schools.

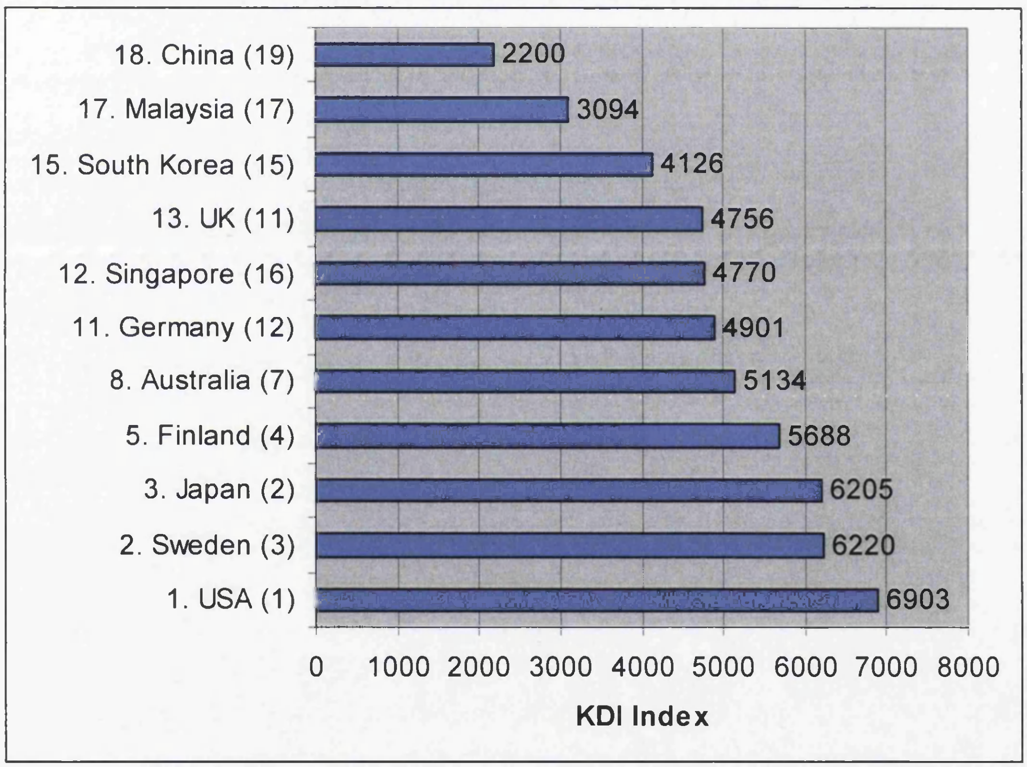


Fig. 4.3 - Knowledge-based Economy Development Index (KDI) [EPU, 2003]

With respect to computer infrastructure and connectivity, Malaysia's position improved for computers in use as a share of worldwide computers in use, the number of mobile telephone subscribers per 1,000 inhabitants and international call costs. For R&D and technology, increases were recorded in the number of scientists and engineers involved in R&D activities and the number of R&D personnel nationwide. However this was weighed down by the decline in other indicators, such as the share of high-technology exports to manufactured exports, total expenditure on R&D as a percentage of GDP and the number of patents granted to residents.

4.1.3 Knowledge-Based Economy Master Plan (KEMP)

With the two main government policies aligned towards achieving a knowledge-based economy to reach developed nation status, it was timely that the Knowledge-Based Economy Master Plan (KEMP) was formulated to provide strategic direction for the nation to develop into a knowledge-based economy over a ten-year period. Initially conceived in 1999 by the Institute of Strategic and International Studies under the guidance of a steering committee headed by the Ministry of Finance, it was proposed in the 2000 National Budget and subsequently published in September 2002 [ISIS, 2002]. Since then, the knowledge-based economy has been commonly dubbed the "K-economy" amongst Malaysians young and old, perhaps a testament to how widespread awareness of this initiative has propagated.

The key message of the document accents on the status of knowledge and education as pivotal factors, particularly in the realms of science and technology. Another key aspect is that human resource development has been identified as the critical driver to thrust Malaysia into a knowledge-intensive economy.

It contains 136 recommendations covering seven areas considered as factors critical to the development of a thriving knowledge-based economy or K-economy in the Malaysian context. These are meticulously outlined in seven strategic thrusts:

- Cultivate and secure the necessary human resources
- Establish the institutions necessary to champion, mobilise and drive the transition to a K-based economy
- Ensure the incentives, infrastructure and infostructure necessary to prosper the optimal and ever-increasing application of knowledge in all sectors of the economy and to the flourishing of knowledge-enabling, knowledge-empowering and knowledge-intensive industries
- Dramatically increase capacity for the acquisition and application of science and technology (including ICT) in all areas
- Ensure that the private sector is the vanguard of the K-based economy's development
- Develop the public sector into a K-based civil service
- Bridge the knowledge and digital divides

To drive home the importance of human capital in the K-economy, 64 of the 136 KEMP recommendations are related to the development of human resources. Much attention is also given to promoting growth of the venture capital (VC) industry, from incentives and tax exemptions, to liberalisation of requirements for technology companies to go for public listings, to increased foreign participation in the VC industry.

The KEMP has moved into Phase 2 (2004 – 2006) and there have been no significant assessments on its effect so far, so perhaps a mid-term review would be timely. But the same external pressures that have influenced the design of the strategic plan are still present, if not increased, so therefore there is the same necessity to stay on track with the KEMP. To quote Dr. Noordin Sopiee, the chairperson and CEO of ISIS:

> *"The fundamental fact is that today's performance is almost always the result of the right things we did in the past, not of the right things we are doing today. If we do not now lay the foundations for the next quantum leap to becoming the economically advanced country of the future, we will hit a brick wall... We have no choice but to change, to now lay the foundation for the next leap forward. If we fail to do so, we will have to say goodbye to Vision 2020. Our dream of becoming an advanced country would have to be consigned to the dustbin of history."*
>
> *[Sopiee, 2002]*

4.1.4 National Science and Technology Policy II (STEP2)

The goals of the first National Science & Technology Policy, as stipulated under the Second Overall Perspective Plan (1991 – 2000) [EPU, 1991], were to ensure continuous scientific and technological development that would support and sustain high rates of economic growth, accelerate overall industrial development and lay the foundation for the attainment of a scientific and technological advanced society by the year 2020. The policy was revised in 2002, and given new directions and objectives, with the same long-term goal of accelerating development of S&T capability and capacity for national competitiveness [MOSTI, 2002]. The impression given by this document was that more tangible targets were set, possibly due to the lack of such targets in the previous plans mentioned above, but more likely due to the policy being set and implemented by basically only one ministry, i.e. the Ministry of Science, Technology and Innovation.

The key R&D targets that were set were; a figure of at least 1.5 % of GDP spent on R&D, and to achieve a workforce of at least 60 researchers, scientists and engineers (RSE) per 10,000 population, both of these targets to be achieved by 2010 [MOSTI, 2002]. This Second National Science & Technology Policy (STEP2) also places great importance on forging linkages between academia and industry. One move with potential significance in technology transfer is the setting of self-financial targets for the operational budgets of public research institutions (30% by 2005) and universities (15% by 2005).

As with the KEMP, the STEP2 also emphasizes human resource development, and this will address the 20-30% shortage of S&T personnel across all levels of scientific, engineering and technical areas, with the situation particularly acute for small and medium scale industries. The specific initiatives include reaching a ratio of students pursuing science, technical and engineering disciplines to business and arts students of 60:40, while at least 10% of those science, technical and engineering undergraduates will be expected to further their studies at postgraduate level. Prominent Malaysian researchers currently based overseas will be given fiscal and non-fiscal incentives to move back home, under the Returning Malaysian Scientists program, perhaps the most visible move to address the brain drain problem.

4.2 Government Ministries and Agencies

4.2.1 Ministry of Science, Technology and Innovation (MOSTI)

Formerly known as the Ministry of Science, Technology and the Environment (MOSTE), MOSTI plays a central part in Malaysia's national innovation system. Most public sector researchers recognize MOSTI's role as primarily to provide federal funding, with the most common grant being the Intensity of Research on Priority Areas (IRPA) funding mechanism. Initiated in 1987 under the Fifth Malaysia Plan (1986 - 1990) and coordinated by the National Council for Scientific Research and Development (NCSRD), IRPA funding is the main source of public funding for research [MOSTE, 2001]. A total of 34 R&D institutions, universities and specialized government agencies are recipients of IRPA grants. Since its inception, IRPA has been allocated RM 3.3 billion ($870 million) from the federal government, as shown in Figure 4.4.

Fifth Malaysia Plan (1986 – 1990)	RM 400 million
Sixth Malaysia Plan (1991 – 1995)	RM 588 million
Seventh Malaysia Plan (1996 – 2000)	RM 1,000 million
Eighth Malaysia Plan (2001 – 2005)	RM 1,363 million

Fig. 4.4 – Approved IRPA allocation from Fifth to Eighth Malaysia Plans, 1986-2005 [Thiruchelvam, 2004]

The priority areas defined in the IRPA guidelines are divided into three groups – experimental research, prioritized research and strategic research. There is a clear emphasis on projects which address the needs of industry, have potential to be commercialised, encourage research collaboration and enhance public and private R&D linkages. These priority areas and the percentage of funding allocated for each are listed in Figure 4.5.

Research Category	% Allocation	Priority Areas
Experimental Applied Research	30	Agriculture and Food Security Natural Resources and Environment Manufacturing and Services Social Transformation Knowledge Advancement
Prioritized Research	35	Manufacturing Plant Production and Primary Products Information and Communication Health Education and Training
Strategic Research	35	Design and Software Technology Nanotechnology & Precision Engineering Specialty Fine Chemicals Technology Optical Technology

Fig. 4.5 – IRPA Priority Areas and budget distribution for Eighth Malaysia Plan [MOSTE, 2001]

Essentially, the funding of IRPA is "bottom up." This means that researchers would propose their research projects to any of the five IRPA panels (Agriculture, Medical, Industry, Strategic and Social Science) which would then decide on their proposals. The latest change to the IRPA scheme requires the submission of monthly and quarterly Financial reports, Milestone Achievement reports at least twice a year, an End of Project report 3 months prior to completion of research, and in special cases a Benefits report no later than 18 months after project completion.

Malaysia's early growth has relied heavily on plantation and agriculture-based industries and public sector R&D has played a significant role in maintaining competitiveness, as well as providing a means of diversification into downstream secondary industries. In the Sixth Malaysia Plan, RM 588 million ($155 million) was spent on 2,329 R&D projects under the IRPA scheme where 48% were agriculture related [Thiruchelvam, 2004]. It is significant that in the case of rubber and palm oil, the R&D effort has been mostly funded and strongly directed by industry. However, this influence has been largely absent in the manufacturing sector where much of the IRPA funded research are not in alignment of actual industry's needs. This disconnection of public R&D in the growth of Malaysian industry to date has meant that links with R&D have not been well developed.

Recently, MOSTI has set up a new division, the Business Development Unit (BDU), intended to be a one-stop centre to assist in all activities related to technology transfer from universities to industry. In 2003, MOSTI through BDU conducted the National Survey on Public Research Commercialisation to investigate why the strong interest in commercialisation displayed by Malaysian researchers did not translate into high results [Hii, 2003]. Hii reported that about 5% of research projects undertaken in Sixth (1991 - 1996) and Seventh Malaysia Plans (1996 - 2000) were commercialised. However, perhaps not surprisingly, the commercialisation had not resulted in significant licensing revenues. The objectives of the survey were to determine the barriers to successful commercialisation, and to gather feedback on the role of the government in enhancing technology transfer. A total of 1000 questionnaires were sent out to active researchers in universities and research institutions, with 383 questionnaires returned.

The survey revealed, among others, that poor commercialisation performance of public R&D was due to weak infrastructure and poor linkages among public research institutions, academia and industry. It found that industry was of the view that services offered by these research institutions and universities were irrelevant to their needs, therefore firm to firm collaboration was more prevalent than collaboration of firms with public research organisations. As shown in Figure 4.6, the key challenges to commercialisation identified in the survey were finding the right management team, gaining access to funding, obtaining support for drafting a business or marketing plan, and achieving market penetration.

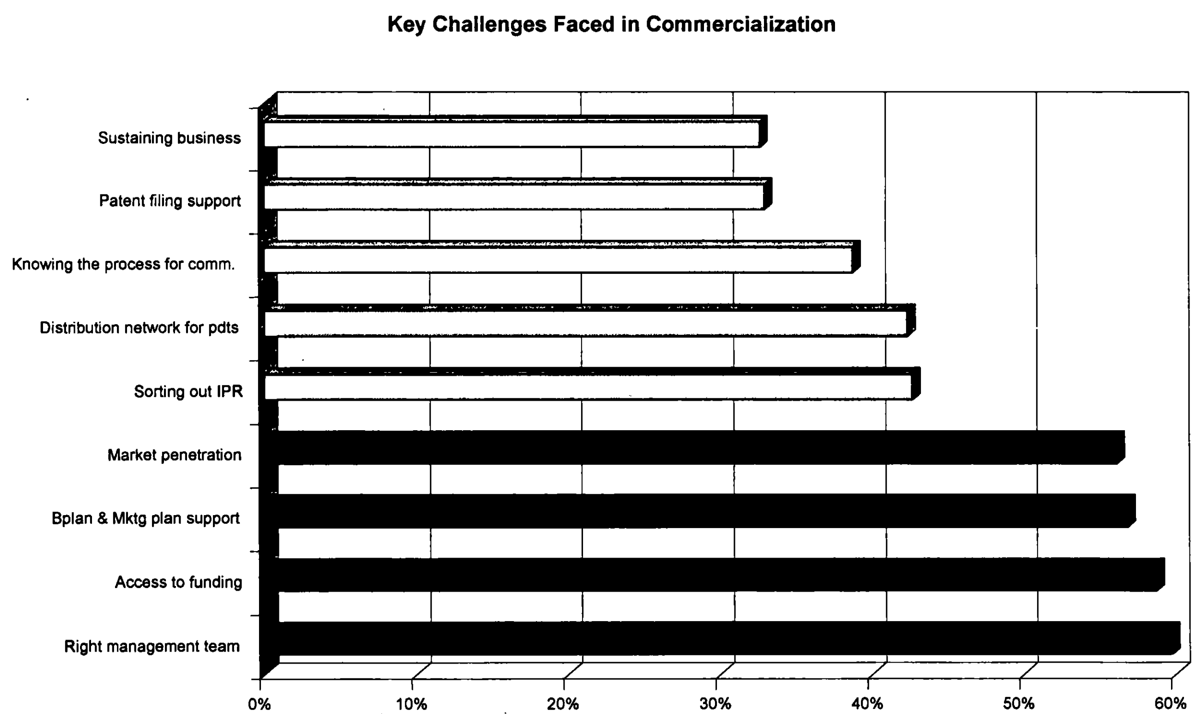


Fig. 4.6 – Key challenges faced in commercialisation [Hii, 2003]

The overall view gained from the survey indicated that the researchers were fairly confident in their research outputs; however, there was a lack of people with business building competence involved in commercialisation activities. Many researchers also revealed that the government should play a more active role in establishing networks and providing the necessary innovation infrastructure.

4.2.2 Malaysian Technology Development Corporation (MTDC)

The Malaysian Technology Development Corporation (MTDC) was established in 1992 as a collaborative venture between the government and industry to become the national body for the commercialisation of research projects and results of Malaysian universities and research institutions and to promote the growth of technology-based enterprises [MTDC, 2005a]. It is a venture capital company under the jurisdiction of the Ministry of International Trade and Industry.

The activity of commercializing research results is undertaken by the technology transfer division of MTDC. MTDC has acted as coordinator to all the business units of local R&D institutions and has successfully commercialised 12 technologies developed by them through technology licensing to private sector companies [MTDC, 2005b]. The number does not necessarily represent the total number of commercialisation projects undertaken independently of MTDC and, therefore, cannot be taken as the measure of the success of commercialisation in Malaysia.

At the same time, MTDC has established 6 start-up companies to commercialise research results through the provision of venture-capital financing to various joint ventures with researchers and universities. Commercialisation of research projects and results has shown some promising results even if such activity is still in its infancy stage. However, there is still room for improvements and strengthening of the mechanisms of commercialisation.

While MTDC is usually referred to as a venture capital firm, it can be argued that by providing government grants, it does not seek the kinds of returns normally expected by professional venture capitalists. In fact, MTDC does provide seed to expansion stage funding for companies not directly involved in the information and communication technology sector. In 1997, the government appointed MTDC to manage grants under the Technology Development Program. The main source of funding provided by MTDC is the Commercialisation of R&D Fund (CRDF), intended to encourage local companies to collaborate with local universities or research institutes in the commercialisation of tangible and manufactured products. Figure 4.7 lists the funding mechanisms managed by MTDC.

	CRDF	**TAF**	**TAF-W**	**Total**
Allocation under 8th Malaysia Plan	RM 40m	RM 73m	RM 25m	RM 138m
No. of Approvals	19	23	30	72
Amount Approved	RM 20.8m	RM 31m	RM 15m	RM 66.8m
% of Utilisation	51.88	42.51	60.22	48.43

Fig. 4.7 – Status of venture capital funds managed by MTDC [MTDC, 2004]

CRDF funding is meant to help the recipient in conducting market research, to product design and development, with provisions for intellectual property protection and up to the proof of concept stage. This is perhaps the most comprehensive technological development grant available from the Malaysian government.

Another government grant awarded by MTDC is the Technology Acquisition Fund (TAF), intended to assist local manufacturing companies in licensing or outright purchase of technologies. Besides formal means of acquiring technology, the fund can also be utilized for employee training programs overseas or to hire foreign experts as consultants. A similar fund for women-owned companies was launched in 1999, under the name of Technology Acquisition Fund for Women (TAF-W) with a provision allowing purchase of equipment and machinery (see Figure 4.7 for the number of approved projects and funds allocated to these two programs).

It is important to note that all funds awarded by MTDC are in the form of partial grants, which means MTDC will not receive anything in return, not even equity in the recipient firm. However, for their venture capital investments MTDC will hold up to 30% equity in a single investee company, and seek at least one seat on the board of directors should the investee get through the expansion stage.

MTDC is by far the most active government agency in terms of commercializing and licensing activities, although the fund size (refer to Figure 4.7) might not reflect this when compared to IRPA or professional venture capital firms. However, MTDC has more established links with industry (through the Ministry of International Trade and Industry), and the stringent criteria for funding approval, coupled with professional fund managers leads one to believe that MTDC is capable of being an integral part of the government - industry linkage within the national innovation system.

MTDC also plays another role as a catalyst for R&D commercialisation through the creation of Technology Development Clusters (TDCs). These clusters are technology incubation centres developed within university campuses to allow companies within specific industries such as biotechnology and multimedia or other knowledge-based industries to operate in close collaboration with the academic staff and scientists or researchers. Through these TDCs, long-term strategic alliances can be developed between the university and industry while this form of networking will facilitate the enhancement of research and laboratory facilities within the campus.

The TDCs are also mechanisms to further enhance technology development programmes within Malaysia as they essentially strengthen linkages between university and industry. So far, MTDC has gained experience in the development of TDCs in four universities, namely Universiti Kebangsaan Malaysia (UKM), Universiti Malaya (UM), Universiti Teknologi Malaysia (UTM), and Universiti Putra Malaysia (UPM). Creating and developing innovative products and processes is time-consuming, and more often than not there is a long gestation period, thus involving substantial costs to the innovator. It is also important to note that state-of-the-art and expensive infrastructure and competent scientists are generally required to carry out the often tedious research activities. Generally, investment can take up many years to translate ideas into marketable products. It is within this context that MTDC was given an important agenda to ensure positive linkages will be developed between universities and industry. To realize this concept, MTDC was provided with an allocation amounting to RM 200 million ($52 million) by the government for the 2001 - 2005 period to develop and establish this programme within the selected universities as indicated above [MTDC, 2004].

4.2.3 Malaysian Industry-Government Group for High Technology (MIGHT)

Another important player in encouraging the development of synergies between the university and industry is the Malaysian Industry-Government Group for High Technology (MIGHT). As an independent and non-profit smart partnership, it was established to undertake technology-prospecting activities for the country [MIGHT, 2005]. Accordingly, it strives to deepen the public-private initiatives to prospect for business opportunities towards increasing national, regional and global competitiveness for Malaysia. In this context, it endeavours to further intensify the exploration of areas of technological and commercial significance for improving industrial performance and the nurturing of indigenous technology-based companies in strategic technology areas.

In this respect through the prospecting process, MIGHT will, among other initiatives, aim at new development in technology by identifying opportunities and to exploit emerging technologies and emphasizing on possible options for participation in collaborative research programmes, opening for new collaborative and synergistic partnerships, and helping the research community to undertake R&D. Ultimately, the prospecting will produce three major outputs, including identifying business and investment opportunities; policy options and interventions; and commercialisation.

In pursuing its objective, MIGHT has adopted the Triple Helix Model which emphasizes on developing strategic collaboration between the government, university and industry so as to utilize the scarce resources within the country more efficiently. Different models of interaction to strengthen collaboration among the three critical components have been tried by both the developed and developing countries. Obviously, the developed nations are in a very advantageous position given the capital and human resources available. Thus, a critical approach should be considered in obtaining maximum linkages and results between research and commercialisation, which ultimately determine the wealth created and competitiveness of the nation on a global scale. MIGHT has demonstrated its commitment to pursuing the Triple Helix model on a collaborative R&D strategy between the three interested parties for the commercialisation of technology and implementation of strategic industrial activities. Under this model, MIGHT tries to exploit the linkages among the key players or stakeholders by capitalizing on shared resources and skills.

One important example anchored on the Triple Helix model is the ongoing COMBICAT Project, involving the upgrading of natural gas and palm oil to higher value added speciality chemicals using Combinatorial Technologies Catalysis [MIGHT, 2004]. The partners involved are Universiti Malaya (UM), Universiti Kebangsaan Malaysia (UKM), Universiti Putra Malaysia (UPM) and three foreign partners from Europe. In this particular project, the role of the Malaysian Government through MIGHT is as an enabler or facilitator by providing adequate funding amounting to RM 50 million ($13 million) and policy support in terms of procurement and hiring foreign scientists. The role of the universities as knowledge-generating institutions is to initiate the potential production of two products through the utilisation of their expertise and skilled work force. They are also expected to develop the fundamental technologies supplemented by some degree of innovation which involves the provision of funding worth RM 6 million ($1.6 million). Finally, the role of the private sector is its willingness to start a new industry and to provide funds of up to RM 20 million ($5.3 million).

4.3 Public Sector Research

In 2002, the Malaysian Science and Technology Information Centre (MASTIC) conducted the National Survey of Research and Development, which was the sixth such survey conducted on R&D activities in Malaysia. The institutions which responded to the survey were from government agencies and research institutions (GRI), universities and other institutes of higher learning (IHL), and private sector companies involved in R&D.

The Gross Expenditure on Research and Development (GERD) of a nation is considered to be a key indicator of knowledge input. Malaysia's GERD has been steadily rising since 1996 as shown in Figure 4.8, passing the RM 1 billion mark ($263 million) for the first time since 1998 and reaching a peak of RM 2.5 billion ($657 million) in 2002. The proportion of R&D spending over GDP has similarly experienced an upward trend, reaching 0.69% in 2002. While this is still a long way to go from the government target of 1.5% in 2010, (as outlined in the Second National S&T Policy (STEP2)) if R&D expenditure maintains its current rate of growth then the target should be achievable.

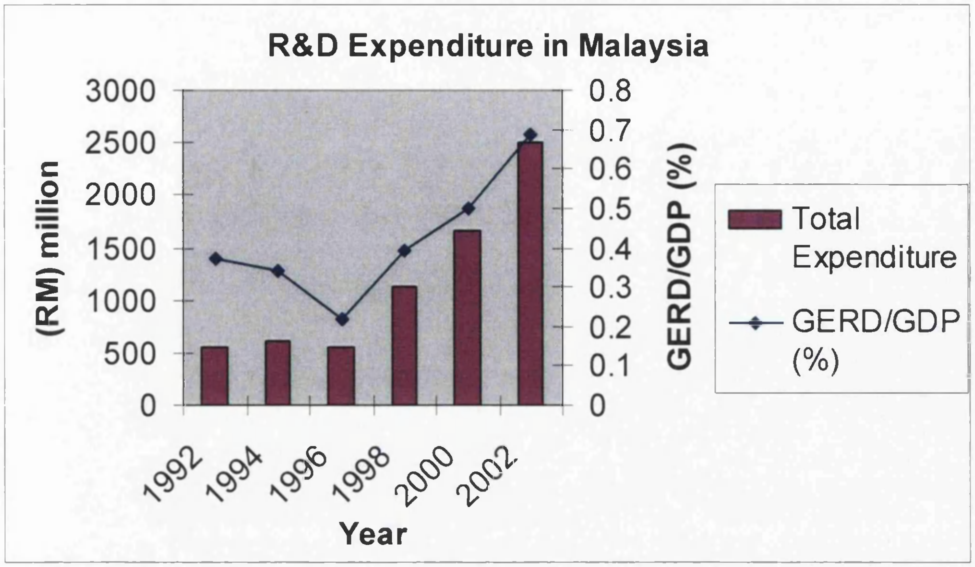


Fig. 4.8 – Total R&D expenditure in Malaysia [MASTIC, 2003]

Overall, the country's R&D activities remained focussed on applied research, followed by experimental research. The emphasis on applied research was more prominent in the private sector, which stresses less on basic research. Similarly, GRIs showed more tendencies to conduct applied research, and IHLs tended to concentrate on experimental research. Figure 4.9 presents a breakdown of research expenditure by type of research.

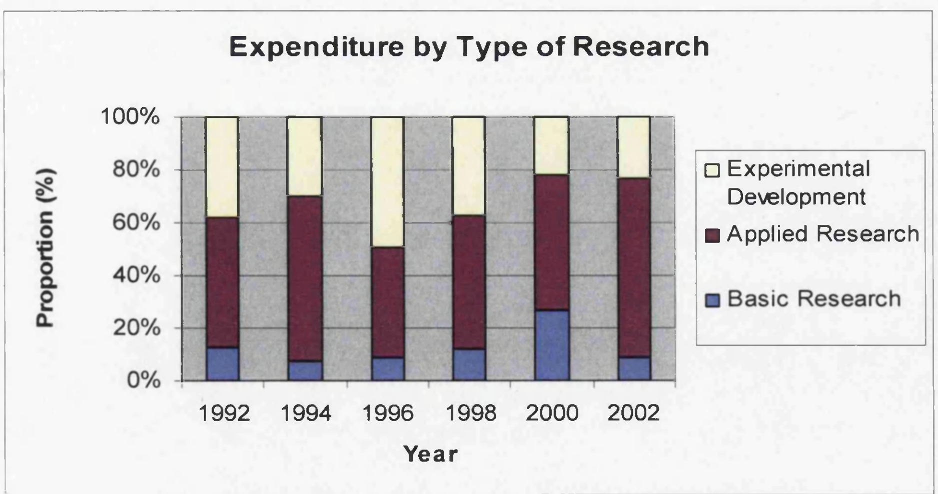


Fig. 4.9 – Expenditure by type of research [MASTIC, 2003]

Funds sourced within the research organisation accounted for most of the R&D funds in 2002, as seen in Figure 4.10. The private sector, throughout the years, have relied primarily on internal funds for R&D activities, and this accounts for the majority of the total R&D funding sourced internally. In 2002, private sector spending reached RM 1.6 billion ($421 million), with 75.8% of those funds coming from within the organisation. GRIs also relied significantly on internally sourced funding, making up 78% of the RM 507 million ($133 million) spent on R&D. However, IHLs were more dependent on external funding, accounting for 66% of their R&D expenditure in 2002.

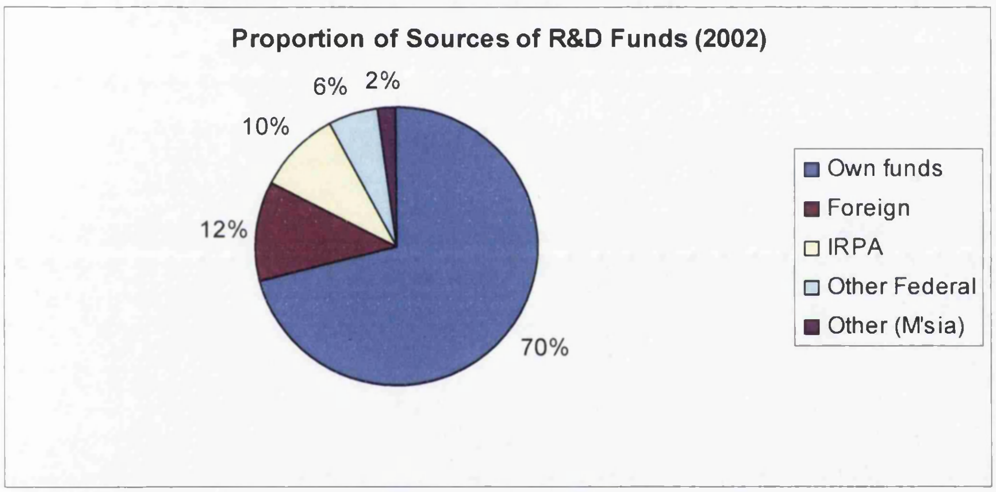


Fig. 4.10 – Proportion of sources of R&D funds, 2002 [MASTIC, 2003]

R&D expenditure in the private sector has always outpaced public sector spending since 1996 (refer to Figure 4.11). However, in 2002 a strong increase in private sector expenditure (from RM 968 million ($255 million) in 2000 to RM 1.6 billion ($421 million) in 2002) has increased the gap between the two sectors, with a result of public sector spending making up only 34.7% of total R&D expenditure. This increase in private sector expenditure could be attributed to the sharp rise in capital expenditure on machinery and equipment, and if so such a sharp rise would not be present for the next few years.

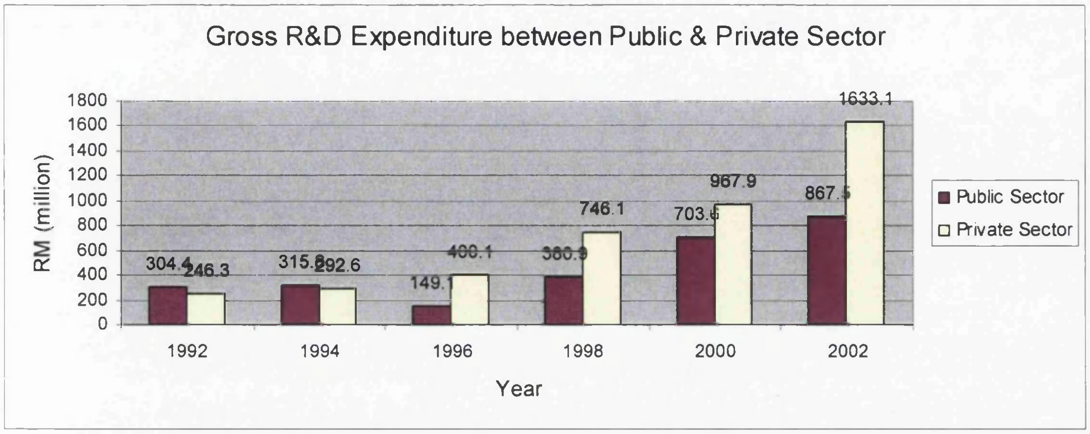


Fig. 4.11 – Gross R&D expenditure between public & private sector [MASTIC, 2003]

External sources of funding for R&D from the federal government (including the IRPA mechanism) amounted to RM 385 million ($100 million) in 2002. Figure 4.12 shows that the main recipients of these federal government funds were public sector organisations, especially IHLs. The private sector, including multinationals received nearly all of the funds they did not source internally from overseas.

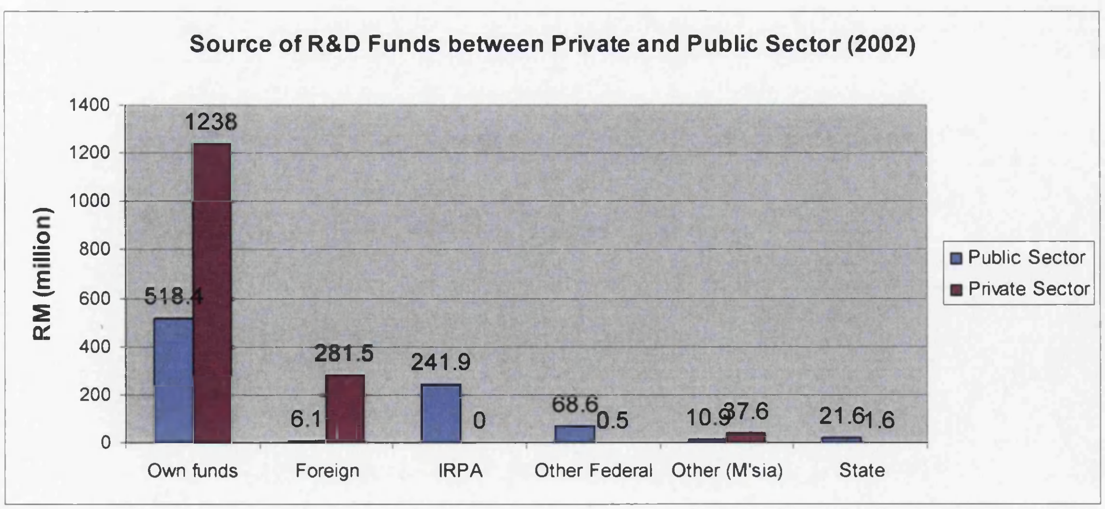


Fig. 4.12 – Source of R&D funds between public & private sector [MASTIC, 2003]

The public sector generally spent more on basic research than the private sector in each year surveyed, except in 2000. On the other hand, the private sector has been spending more on applied research than the public sector since 1996. In 2000 and 2002, public sector spending on experimental research increased, with more funding going towards research in Agricultural Sciences and Biological Sciences (refer to Figure 4.13). However, some confusion has arisen from such an increase of spending. Based on the clarification provided by MASTIC [Mani, 2004], the data on the source of funds for private sector R&D were not broken down to reflect the years, and were in fact for the whole survey period. This was due to inaccurate documentation in the questionnaire.

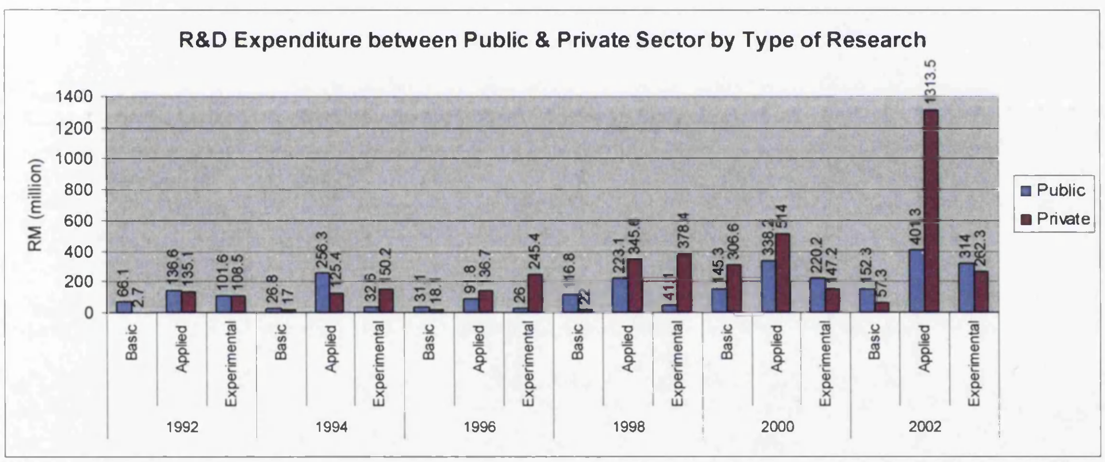


Fig. 4.13 – R&D expenditure between public & private sector by type of research [MASTIC, 2003]

Another recognized indicator for technological and innovative capacity is the number of full-time researchers. The government has set a target, through the STEP2, of 60 full-time research personnel per 10,000 population by 2010, and it is necessary that Malaysia increase this factor rapidly, with the 2002 figure at 18 researchers per 10,000 population. The number of full-time researchers employed in the public sector was considerably higher compared (66%) to the private sector in 2000 and

2002. However, the relatively small increase in public sector researchers might indicate a trend of migrating to the private sector. Figure 4.14 shows the number of full-time R&D personnel by sector from 1992 to 2002.

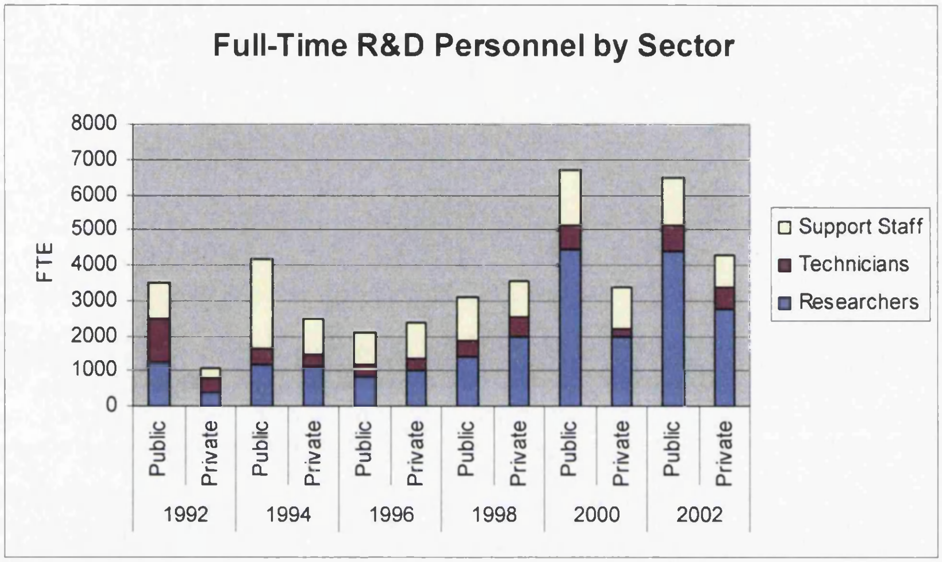


Fig. 4.14 – Full-time R&D personnel by sector [MASTIC, 2003]

There was also a notable increase of 6.5% in the total number of female R&D personnel, but the proportion remains relatively unchanged. However, women continue to account for one-third of the total researchers in the country. This is expected to increase, given the increasing proportion of female to male graduates in universities.

While R&D expenditure and full-time researchers are considered strong metrics to study the knowledge 'input' of a national innovation system, there are also studies conducted to assess the knowledge 'output' as well. One of the indicators easily measured is the bibliometric output, or scientific papers published in recognized journals. In 2003, it was noted that while research funding had been steadily increasing, there was a corresponding decline in the rate of papers published in journals. Therefore, MASTIC decided to carry out the 'Science and Technology Knowledge Productivity in Malaysia Bibliometric Study 2003', primarily to identify the outputs of Malaysian S&T research activities in terms of scientific publications at the international level, covering a period of more than 30 years (1970 – 2002).

As shown in Figure 4.15, it was found that the country experienced a slow growth of S&T knowledge outputs for the period 1955 – 1980, when less than 100 papers were published in international journals within every two years during the period [MASTIC, 2004]. There was a surge of outputs from 1981 to 1982, perhaps coinciding with the industrialisation sweeping the country, and growth was steady until 1994, when the rate of papers published began to increase again.

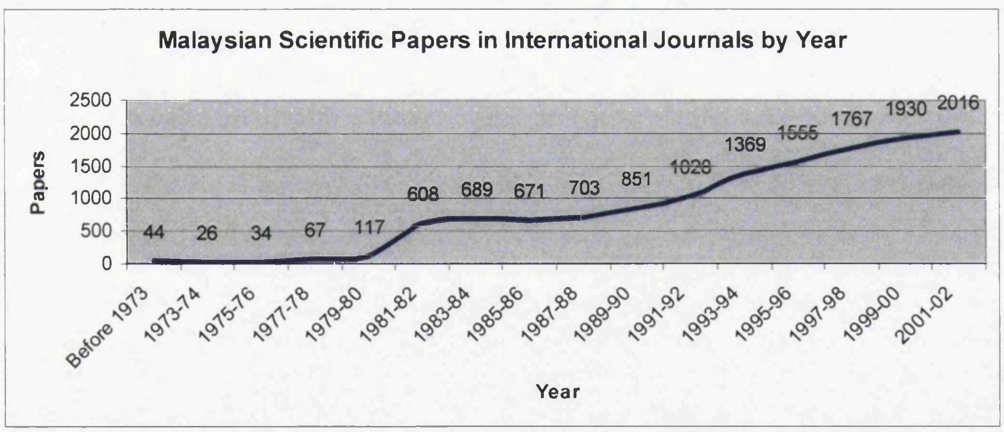


Fig. 4.15 – Malaysian scientific papers in international journals [MASTIC, 2004]

The study then assigned subject headings to the published papers, according to MASTIC's own classification [MOSTI, 2003] along with Thomson-ISI's Science Citation Index subject classification. Figure 4.16 displays the top ten fields with the highest productivity, comprising 46.14% of the 13475 total papers published. It is interesting to note that one single scientist, Fun Hoong Kun from Universiti Sains Malaysia, contributed to almost half (602 papers) of the total papers written on Physical Chemistry. More relevant to the topic however, it can also be noted that most of the fields of research on which extensive publications have been written do not lend themselves to straightforward adoption by industry.

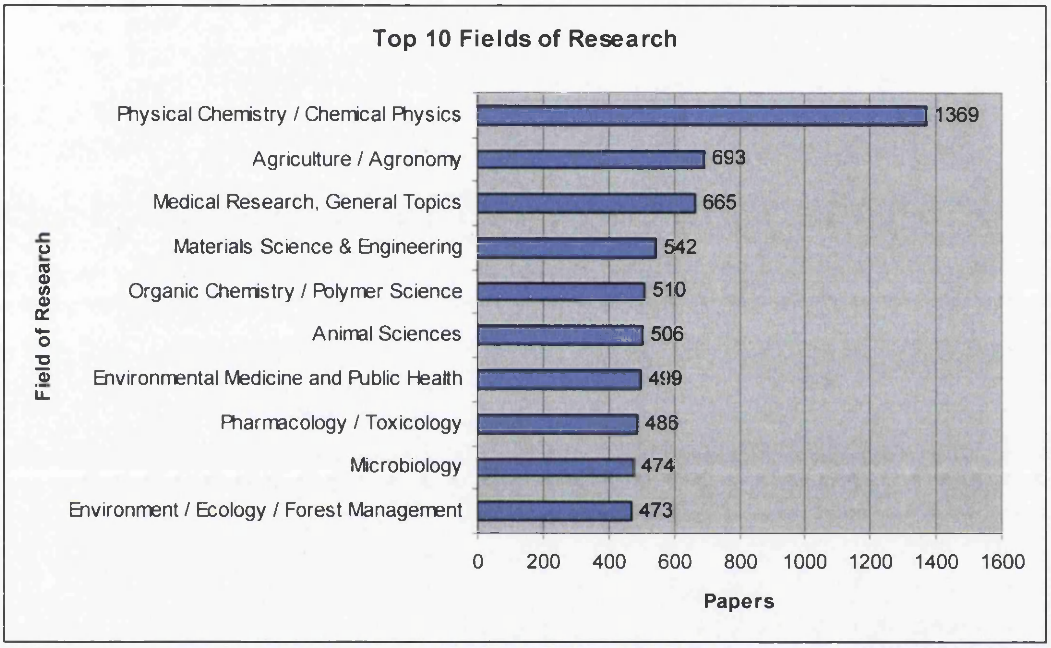


Fig. 4.16 – Top ten fields of research [MASTIC, 2004]

The study concluded with an international comparison of contributions to world science, where Malaysia ranked 55th out of 178 countries, contributing only 0.08% of papers to the total S&T papers worldwide.

4.4 Innovation in the Private Sector

The manufacturing sector has been the key driver of economic development in Malaysia since the 1980s, and continues to be targeted as such as outlined in the

Third Outline Perspective Plan [EPU, 2001]. However, shifting to a new phase of industrial development, in line with the move towards a knowledge-based economy requires emphasis on innovation, in this case defined by new and improved products, processes and operations.

In 2001, MASTIC carried out a survey to assess the level of innovation in the manufacturing sector. The methodology used in the survey was adopted from both the OECD Oslo Manual [OECD, 1997], a guideline on data collection on technological innovation, and the Third Community Innovation Survey (CIS-3), a series of national innovation surveys carried out by European Community countries. 4000 questionnaires were sent out to manufacturing firms, with 749 completed questionnaires received [MASTIC, 2001].

Out of the 749 questionnaires received, 263 firms (35%) revealed that they carried out innovative activities (refer to Figure 4.17), which was an increase from the previous percentage of respondents (21%) recorded in the previous national innovation survey.

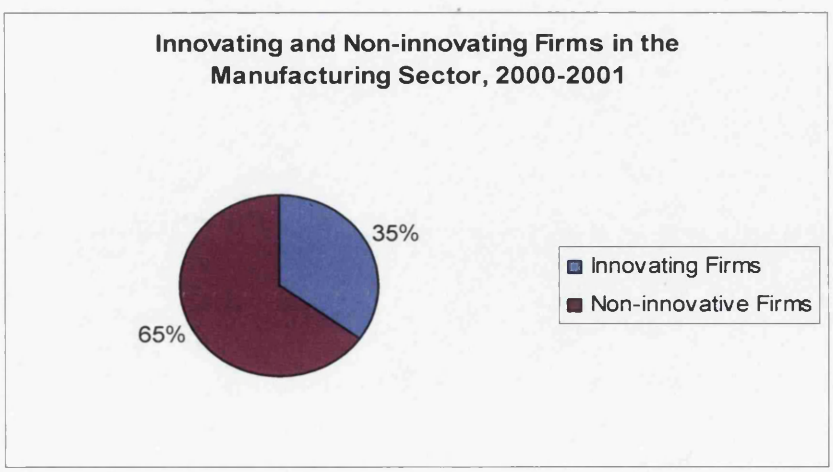


Fig. 4.17 – Innovating and non-innovating firms in the manufacturing sector, 2001 [MASTIC, 2001]

One of the findings of the survey showed that innovating firms tend to be larger in terms of employees than non-innovating firms. Firms with less than 20 employees made up 32.3% of innovating firms and 55.1% of non-innovating firms. Conversely, 25.1% of innovating firms had 250 employees or more, while the percentage was 7.2% for non-innovating firms. This indicates that small employment size is not a constraint to innovation in firms.

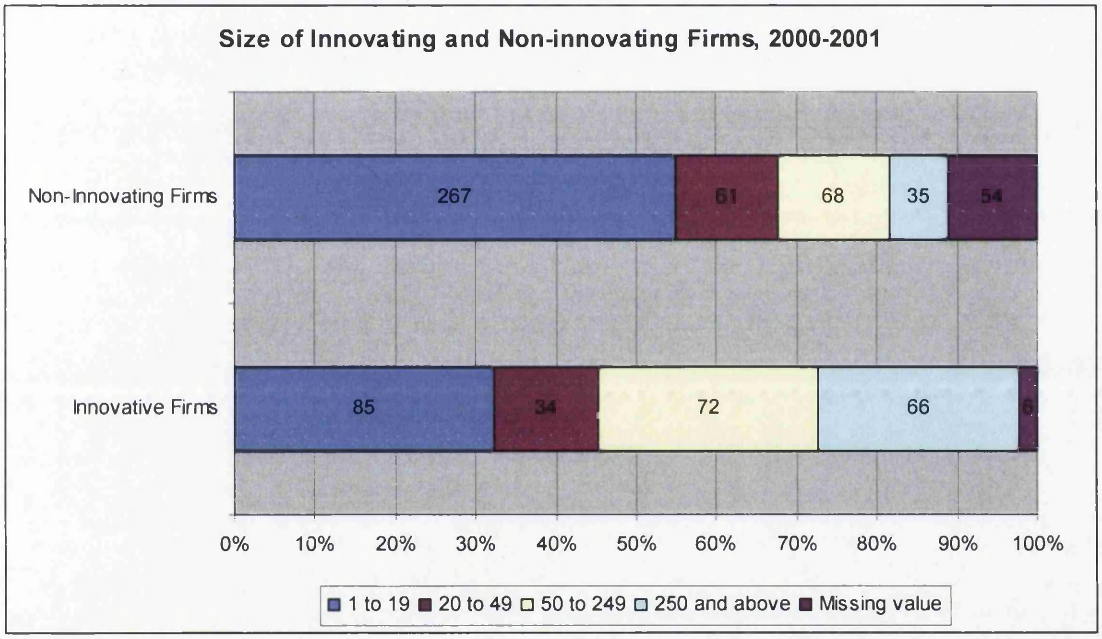


Fig. 4.18 – Size of innovating and non-innovating firms, 2001 [MASTIC, 2001]

Smaller firms also tend to be more innovative in terms of new products and processes, as well as projects currently in progress, which are expected to yield innovative results. This is shown in Figure 4.19, which presents a typology of innovation by employment size. The second largest number of innovating companies fall within the 50-249 employees category, followed by the firms with 250 employees and above, which follows the general profile.

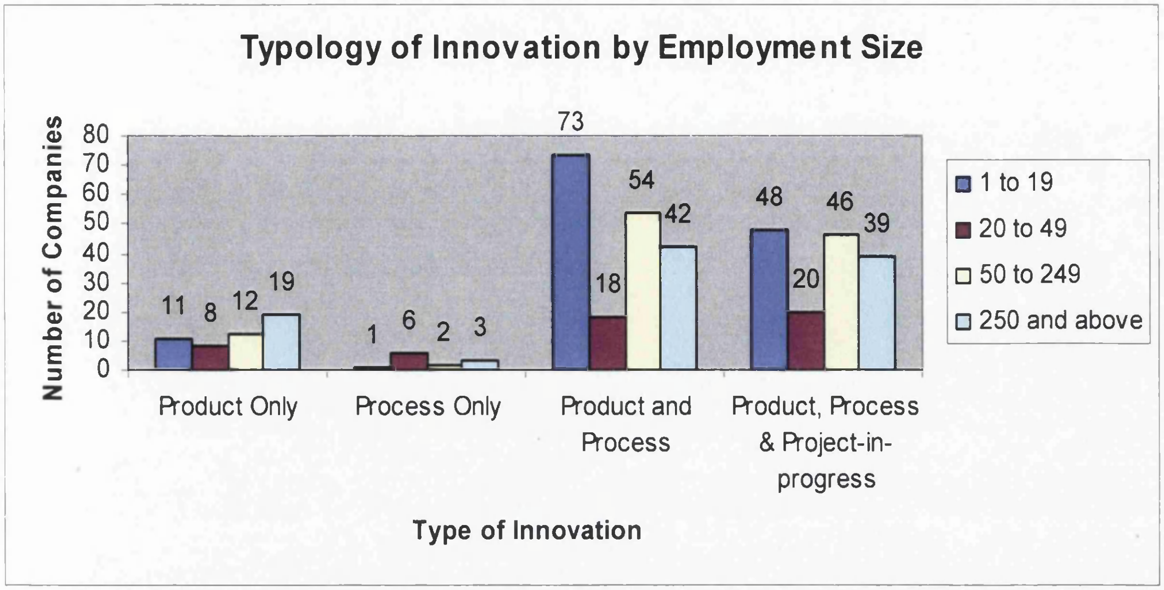


Fig. 4.19 – Type of innovation by employment size, 2001 [MASTIC, 2001]

There are many factors encouraging firms to innovate, from fulfilling regulations and standards, to achieving more sustainable development, to increasing their competitive advantage. Significantly, the survey indicated that more than 80% of firms (210 firms) responded to improving the quality of their products as the highest impact in motivating them to innovate. The other four objectives to innovate with a high impact (i.e. ranked highly by more than 100 companies) were to extend the range of products offered, improve flexibility of production, to open up new markets or increase market share, and to comply with regulations and standards. This gives the impression that innovation in the private sector is driven by market forces. The objectives for innovation according to the firms surveyed are presented in Figure 4.20.

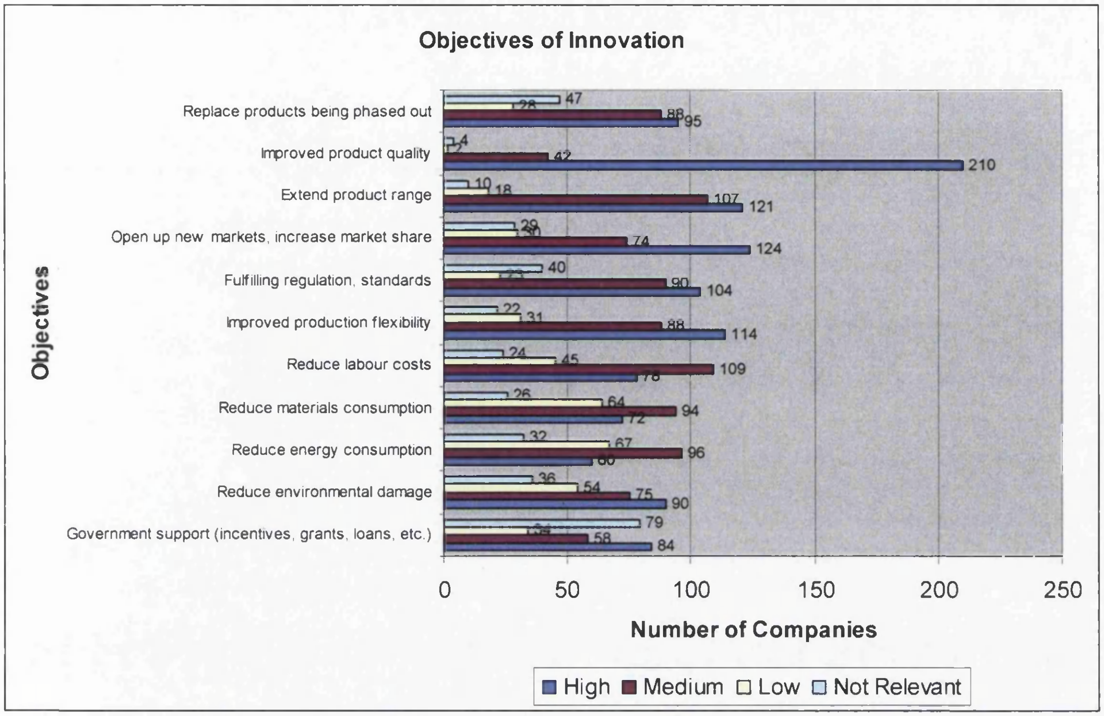


Fig. 4.20 – Objectives of innovation [MASTIC, 2001]

It is interesting to note that amongst the factors ranked as not relevant, governmental support received the most responses (79 firms, or 31%). Conversely, 33% of the innovating companies ranked government support as the highest impact on their involvement in innovation activities. This indicates that governmental policies with respect to innovation in the private sector are mismatched, and lack focus in selecting the target group, however on the whole the impact of these policies do not play a big part in encouraging innovative activities in firms.

Figure 4.21 shows that the number of companies that have benefited from government support and incentives are insignificant compared to those who have not received such support. Out of 257 companies that applied for government support, assistance, and incentives from the government, only 11 companies (4%) reported having received financial support. The firms that applied for technical consultancy and support services and tax incentives from the government also reported similar poor percentages. Only three firms managed to receive the Commercialisation of R&D Fund (CRDF) from MTDC. The bulk of the support granted was intended for duty free importation of machinery and equipment, as indicated by 56 companies (22%). These findings point to an inefficient delivery system for support channelled from the government to promote innovation.

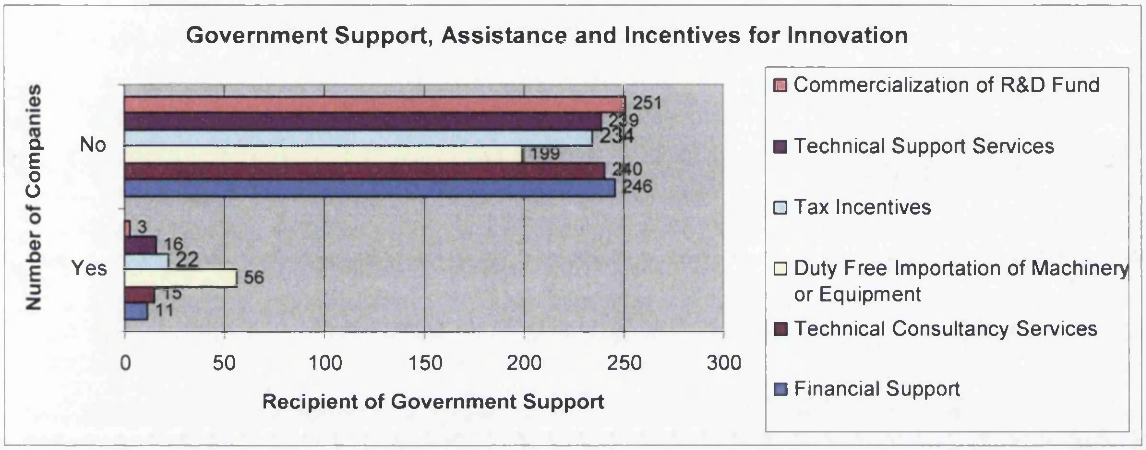


Fig. 4.21 – Government support, assistance and incentives for innovation [MASTIC, 2001]

Apart from the motivation to innovate, it is also pertinent to consider the sources of information for innovation. The innovating companies' clients or customers appear to be the most important factor, as indicated by 57% of the innovating firms (146 companies), as shown in Figure 4.22. This again confirms the previous finding that innovation in the private sector is market–driven. On the other hand, patent disclosures and universities appear to have less bearing as sources of information as only a relatively small number of companies (less than 10%) indicate those factors as having a high impact on them.

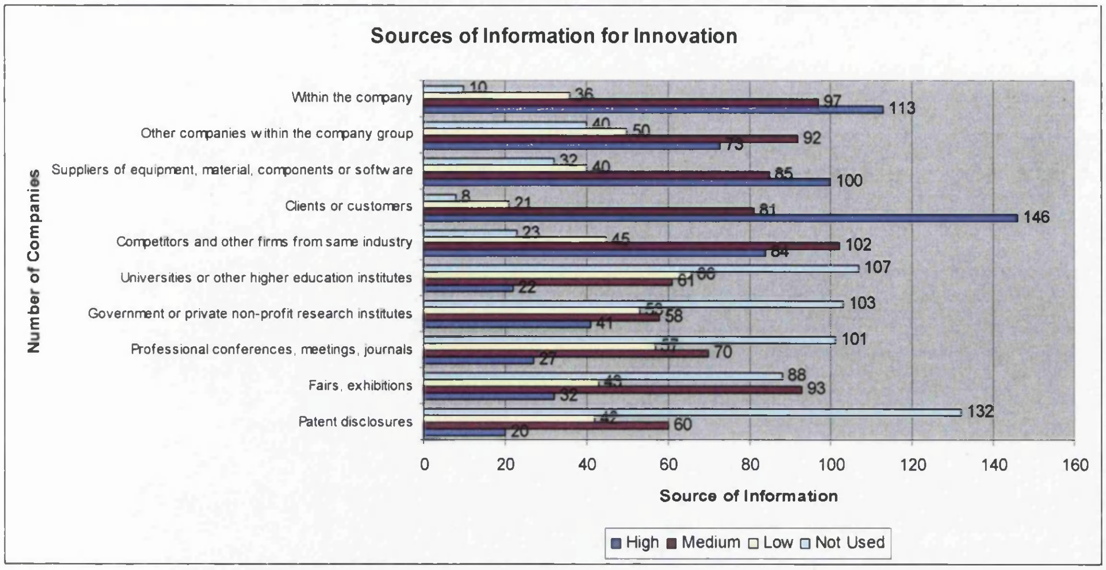


Fig. 4.22 – Sources of information for innovation [MASTIC, 2001]

The importance of market-driven sources of information is further confirmed by the relatively small number of companies that indicated they did not use information from their clients (8 companies), or internal information as sources for innovative activities (10 companies). In contrast, patent disclosures had the largest number of companies indicating that they were not used as a source of information (132 or 57%). In addition, 107 innovating companies also revealed that they did not see universities as sources of information, confirming the weak university-industry link in the country. Similarly, there is also an implied weak link between the government or private non-profit research institutions, as 103 of the innovating companies did not use them as sources of information.

An overwhelming number of companies sourced their development of new and improved products or process internally. While this is not representative of collaboration towards innovative activities as a whole, it is worth considering that the first steps towards innovation taken by these 204 firms, or 78% of companies, begin without input from external sources (refer to Figure 4.23).

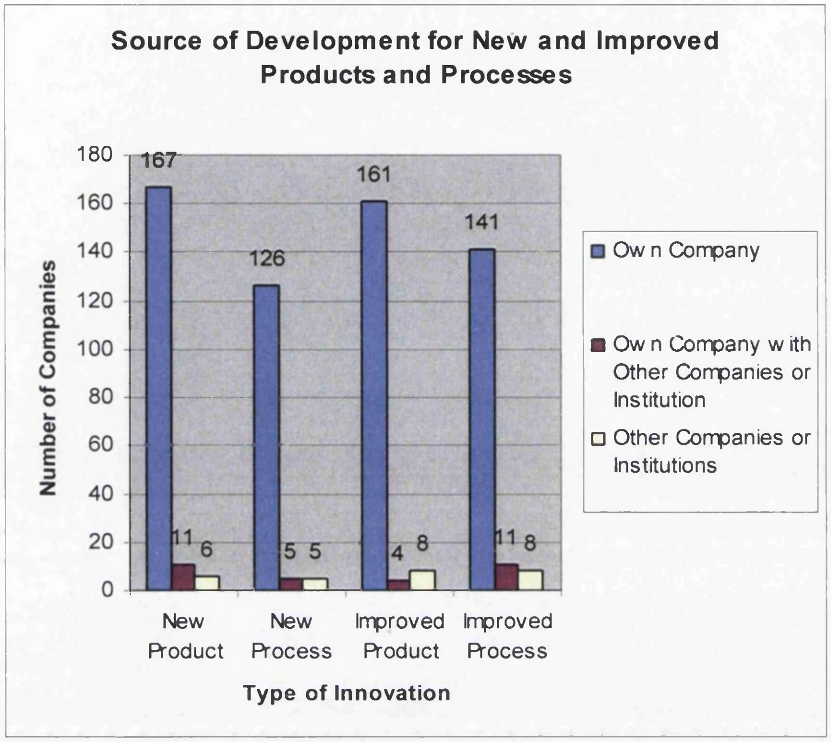


Fig. 4.23 – Source of development for new and improved products and processes [MASTIC, 2001]

As for the 55 innovating firms (21%) that reported having co-operation agreements on innovation activities, the two strongest partners for such collaboration were the clients and suppliers of equipment (19 companies each). This pattern is similar to foreign innovating firms and multinational subsidiaries based in Malaysia, mainly Japan, UK and USA. This trend of co-operation, as shown in Figure 4.24, perhaps reflects the relationship between trade and investment patterns, influenced by the intra-firm trade common among multinationals.

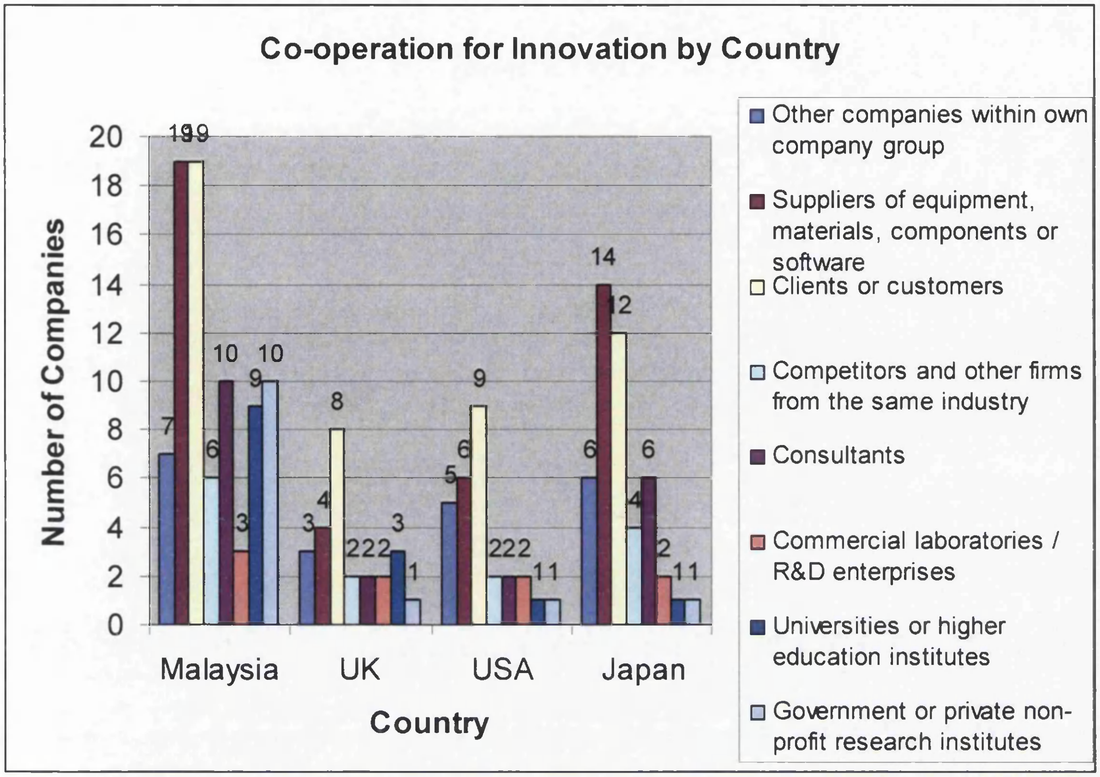


Fig. 4.24 – Co-operation for innovation by country [MASTIC, 2001]

With Malaysian firms, co-operation with consultants, universities and government research institutions are the next three most frequent partners for collaboration. On the other hand, commercial laboratories and research enterprises are less frequently, except in the case of foreign partners. Nevertheless, the indication on co-operation with clients and suppliers indicates that the vertical chain for adding value shows great potential for innovation.

The great barriers to innovation in the private sector however, are shown in Figure 4.25 to be financial, namely the high cost of innovative activities and the perceived lack of sources of financing. Unskilled personnel perceived economic risks, lack of information on technology and lack of market information are also important factors hampering innovation. These findings were found to be similar to the previous innovation study in 1999.

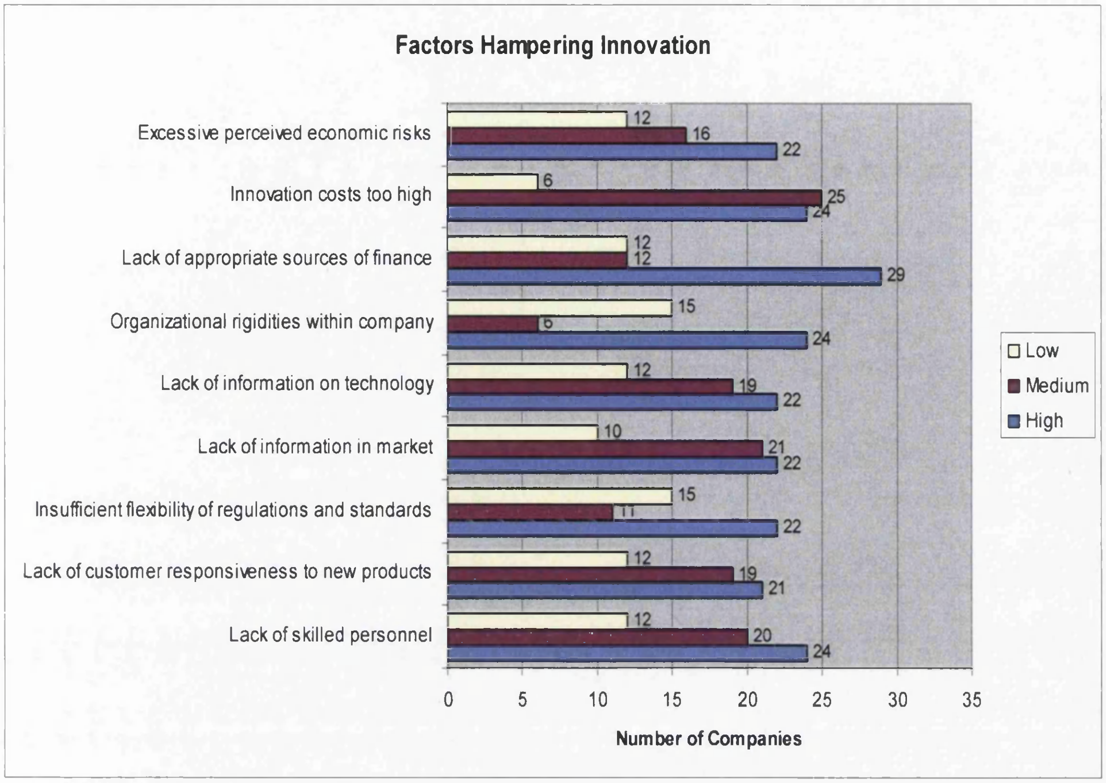


Fig. 4.25 – Factors hampering innovation [MASTIC, 2001]

4.5 Technology Parks and Incubators

Malaysia has invested heavily in technology infrastructure to support the development of its industrial technological capabilities. Most of the nation's industries are located in over 200 industrial estates or parks throughout the country, but specialised parks have been developed to cater to the needs of technology-intensive industries and R&D activities, and the trend is increasing.

The Kulim Hi-Tech Park (KHTP), located in the northern state of Kedah, was the first fully developed high technology industrial park in Malaysia. Officially opened in 1993, the RM 1.2 billion ($316 million) project was undertaken by Kulim

Technology Park Corporation, a wholly owned subsidiary of the Kedah State Development Corporation.

With planning and design assistance from the Japan International Cooperation Agency (JICA), KHTP which covers an area of 1,450 hectares incorporates numerous functions, among them industrial, research and development facilities and a new township concept with full amenities including a shopping centre, medical and educational institutions and recreational facilities.

The premier technology park is Technology Park Malaysia (TPM), located on 310 hectares of prime land in Bukit Jalil in Kuala Lumpur, in the heart of the Multimedia Super Corridor. TPM was developed in 1988 by Technology Park Malaysia Corporation, with the aim of providing quality infrastructure and services to select innovators and companies engaged in high-tech industries [TPM, 2004]. The first phase of the park, which comprised a total of 12 buildings and 10 R&D lots on a 73-hectare plot, has been completed at a cost of RM 237 million ($62 million); while the second phase, valued at RM226 million ($60 million) was completed according to schedule in 2000.

Upcoming technology parks include the Composite Technology City in Melaka as well as the Subang Industrial Aerospace Park and Avionics Park, both in Selangor, which are set to play an important role in building the country's high-tech base. These three parks are expected to house corporate, academic and government tenants specializing in R&D activities related to electronics, telecommunications, new materials and biotechnology.

In addition, the Natural Resource Park in Sarawak and the Science Parks in Penang and Johor are expected to generate extensive innovation and R&D activities, particularly in the fields of plant biotechnology, microelectronics and communications, respectively.

Malaysia's first incubator programme was established at Technology Park Malaysia (TPM) in Bandar Tun Razak, Kuala Lumpur, in 1988. Subsequently, in 1995, it was moved to its permanent site at the TPM Bukit Jalil. Under the incubator programme, TPM develops and maintains an Innovation House, Incubator Centres, Enterprise Houses, a Resource Centre and a Recreation Centre. Besides providing operational space, the programme also provides centralized facilities such as 24-hour security and property management, Internet and local network connectivity, conference and meeting rooms, telecommunication conference facilities and services, an exhibition area, and a learning centre for training facilities and services. Apart from TPM, other incubator providers are the Malaysian Technology Development Corporation (MTDC), which operates four incubation centres in local universities (as mentioned above) and the Johor Incubation Centre.

The ultimate objective of setting up incubation centres is to stimulate the growth and development of indigenous IT-related activities by individual innovators. These incubation centres are structures that serve as temporary reception centres to newly formed companies or those in the process of being created, providing them with an environment favourable to their development. Their targets are small firms that may lack the management, technical and financial ability to survive on their own, but which can gain tangible benefits from the common support services.

Small businesses in incubators can keep overhead costs manageable by paying for services on a shared, fee-for-service basis. Cash flow benefits, access to assistance sources and interaction with other entrepreneurs in an incubator have been proven to greatly improve the chance of success for start-up companies. As Malaysia moves further towards a k-economy, more incubation centres will be set up to nurture the growth of budding technology companies.

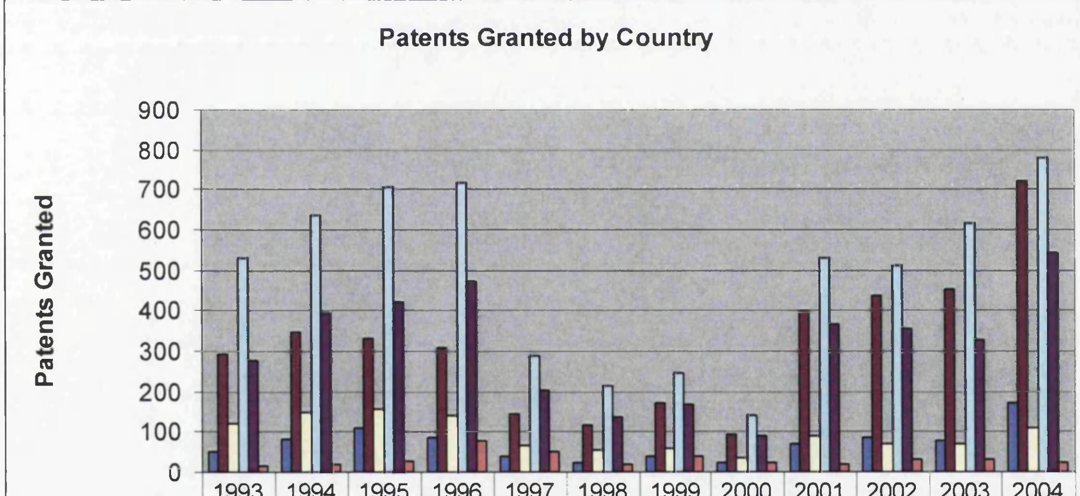
4.6 Intellectual Property Protection

Technological patents are considered the main indicator of knowledge 'output', although this has been the source of much recent debate. It is up to the patent office of each country to manage the provisions for protecting intellectual property rights, though agreements like the Patent Cooperation Treaty are intended to standardize and streamline this process, if at least at the international level.

Malaysia has partly inherited the intellectual property system from the UK, with the significant legislations being the Patents Act 1983, the Trade Marks Act 1976, the Industrial Designs Act 1996, and the most recent being the Layout Designs of Integrated Circuits Act 2000. While the last act mentioned was implemented to protect Malaysia's high-tech exports industry, it is interesting to note that Malaysia currently has no plans to introduce software patents, a point of contention throughout the world and the EU in particular. In 2000, the Malaysian Intellectual Property

Corporation Act was established, resulting in the corporatisation of the patent office and subsequent rename to the Intellectual Property Corporation of Malaysia (MIPC), under the jurisdiction of the Ministry of Domestic Trade and Consumer Affairs.

Malaysia is a member of the World Intellectual Property Organisation (WIPO) Convention, the Paris Convention (Industrial Property) and the Berne Convention (Literary and Artistic Works), as well as being a signatory to the TRIPS Agreement, and is currently in the process of implementing the Patent Co-operation Treaty. Sadly, despite relatively strong legislation, and membership and ratification of international IP treaties, Malaysia is still lacking in patents as technological outputs. Figure 4.26 displays the total number of patents granted by country in Malaysia.



	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
Germany	52	83	108	84	40	24	40	23	71	85	77	171
Japan	293	348	330	309	145	118	173	94	397	437	453	720
UK	120	147	157	139	66	55	58	34	88	71	72	110
USA	529	637	707	717	287	213	245	139	530	512	617	779
Others	276	393	422	473	203	135	166	91	366	355	328	543
Malaysia	14	21	29	79	52	21	39	24	18	32	31	24

Fig. 4.26 – Patents granted by country [MIPC, 2005]

The difference between patents granted to Malaysians and foreigners is hugely disproportionate, and is a telling indicator of the state of local technological capacity. This may be due to the lack of awareness of both university researchers and local inventors. Perhaps to a certain extent local industries are to blame as well, as seen in their unwillingness to finance intellectual property protection for their products. A cursory glance at the statistics for the number of local patents applied (and granted) might give the impression that MIPC too is at fault for not processing the applications efficiently (refer to Figure 4.27).

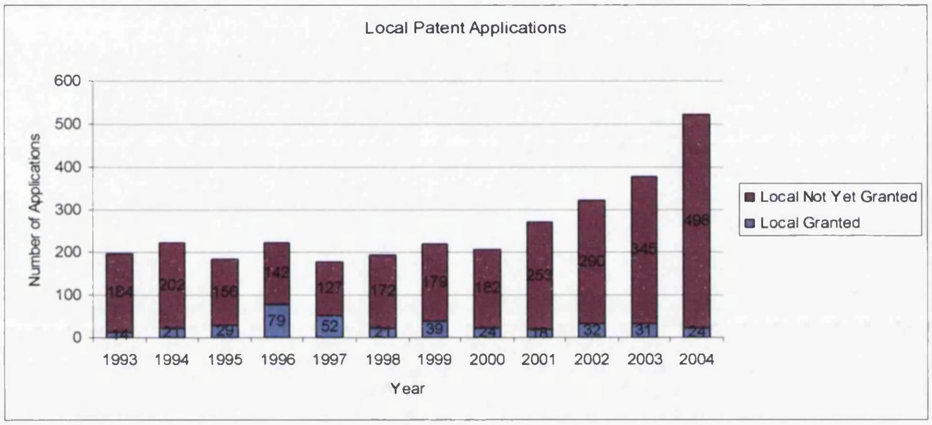


Fig. 4.27 – Local patent applications [MIPC, 2005]

However this is certainly not the case when the statistics for foreign patent applications are considered, for example in 2004 the number of foreign patent applications which were not yet granted is four times as much as the total number of local applications, as seen in Figure 4.29. The huge disparity between local and foreign patent applications is due to the dominance of foreign multinationals, which are more keen to pay for IP protection. However the low rate of patents granted per applications still applies to both local and foreign patent applications, and MIPC has taken steps to resolve this issue by hiring more personnel and initiating dialogues with members of industry and academia.

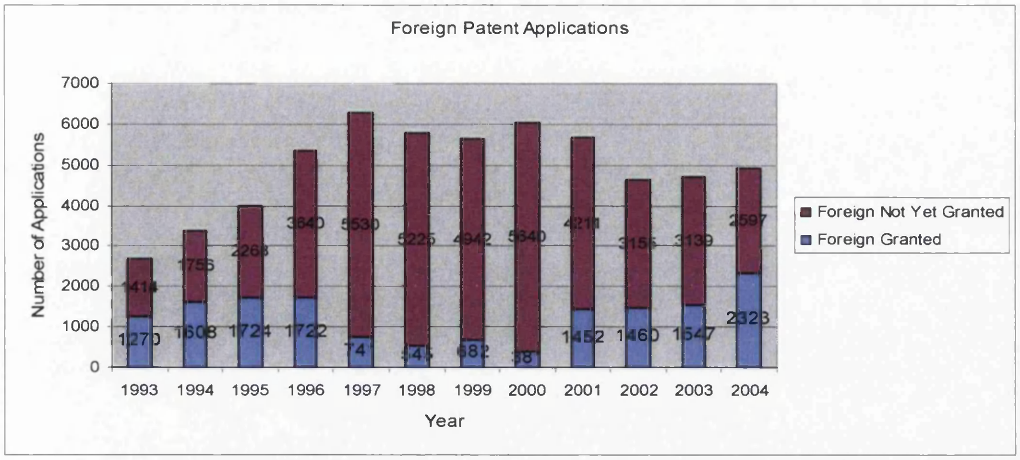


Fig. 4.28 – Foreign patent applications [MIPC, 2005]

4.7 Analysis on R&D Efficiency

The secondary data collected was analysed to determine the relationship between R&D funding and the relevant outputs. Figure 4.29 displays the amount of public and private sector spending on R&D and the share of GERD over GDP. There was a general increase in R&D spending on the whole, beginning from 1996. It can be seen here and elsewhere (Figure 4.11) that private sector expenditure on R&D has been significantly higher than the public sector, especially in 2002 when the difference was almost twice as much.

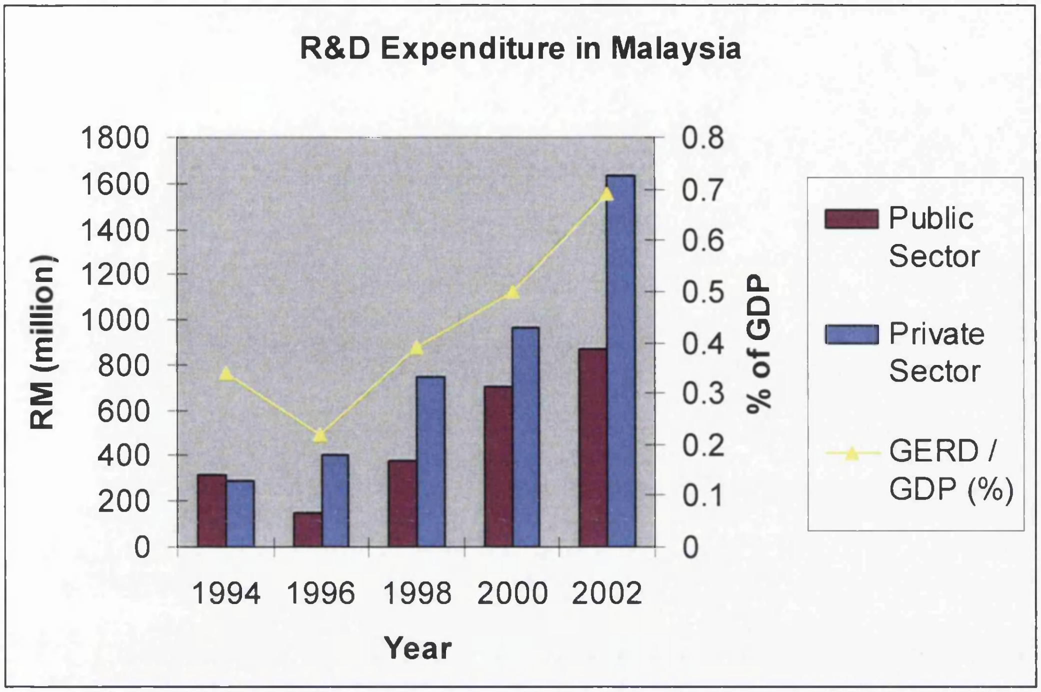


Figure 4.29 – R&D Expenditure in Malaysia [MASTIC, 2003]

A graph showing the number of patents applied and granted by local applicants was previously presented in Figure 4.27. As patents are generally recognised as a metric to study innovation, the number of patents registered by Malaysians locally and in the US was observed to see if there was a correlation between research expenditure and patents.

Figure 4.30 shows that there has been an overall decline in the number of local patents granted to Malaysians, though this is not due to the lack of applications (see Figure 4.27). On the other hand, there was a slight increase recorded for patents registered in the US by Malaysian applicants. However both figures do not reflect the increase in research expenditure from 1996 onwards, therefore it can be reasoned that there was minimal impact on patents being granted compared to the amount spent on research.

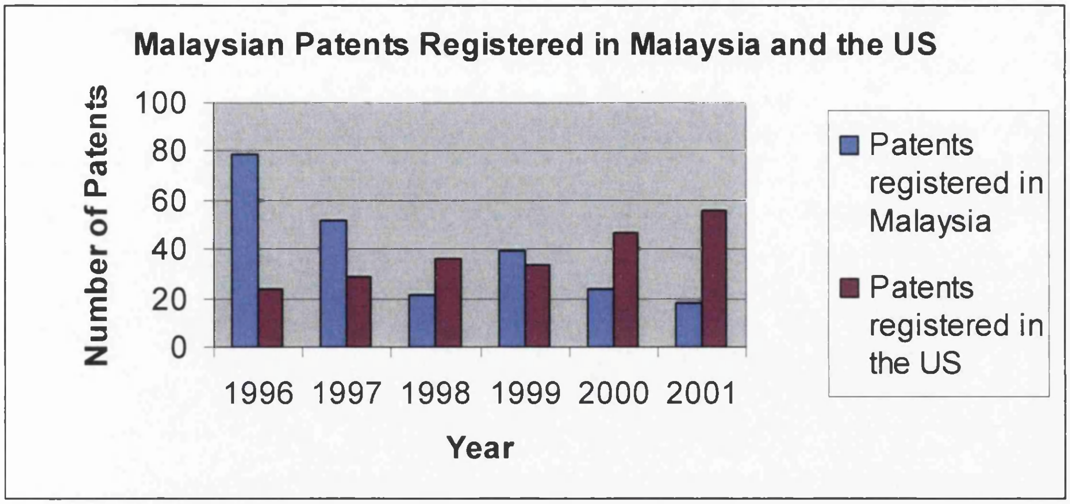


Figure 4.30 –Patents registered by Malaysians, locally and in the US [Mani, 2004]

Another area to be examined was the effect of research spending on the economy, specifically the high-technology industries in the manufacturing sector. High-tech industries in this case are limited to the aerospace, computers and office machinery, electronics, and pharmaceutical industries. These industries are deemed to have a high knowledge content, as the R&D performed in these four industries comprise 45% of R&D performed across all sectors worldwide (48% in the US) [Rausch, 1998].

The value of these high-tech industries and their share of total manufactured exports are presented in Figure 4.31. These industries maintained their total worth at under RM 250 billion (US$ 66 billion) from 1996 to 2001, with the exception of a slight increase in 2000. However, there was steady growth recorded in the case of the share of manufactured exported goods, with the high-tech industries making up 54% of Malaysia's manufactured exports in 1996 and reaching a peak of 62% in 2000.

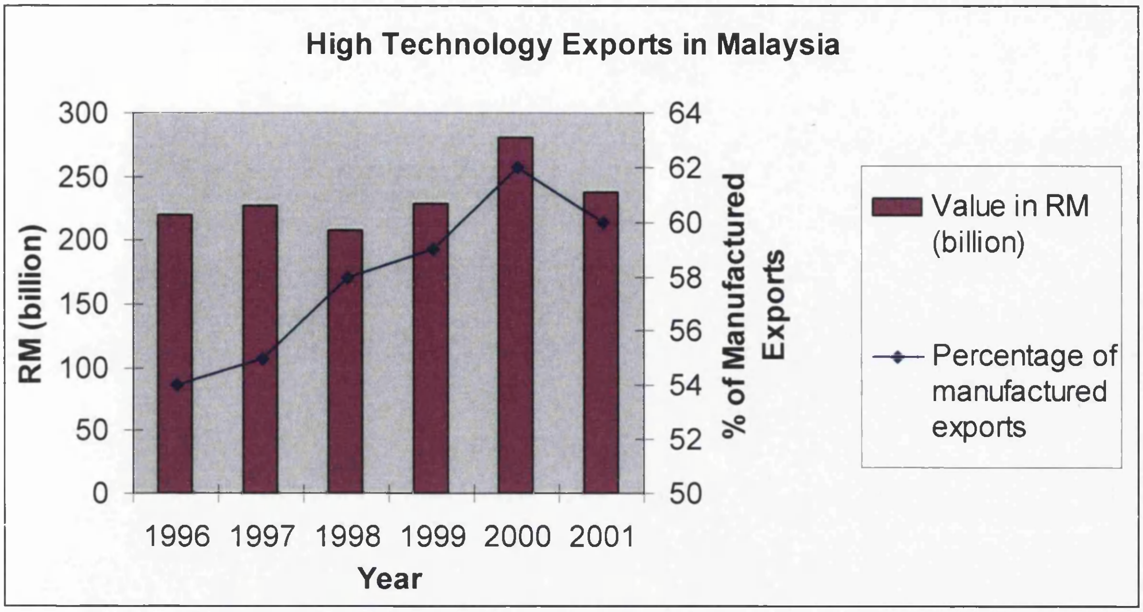


Figure 4.31 – Value and share of high technology exports in Malaysia [World Bank, 2003]

From the previous figure on R&D expenditure, it can be seen that the increase in R&D expenditure mirrors the growth of Malaysia's high-tech industries' share in the manufacturing sector (except for a 2% decline in 2001). While the growth in this area may be attributed to increased spending on R&D, the same cannot be said on patenting intellectual property. Therefore from these figures it can be concluded that there is a significant relationship between R&D funding and growth in the high-tech industries' share of exports.

5.0 CHAPTER V – FINDINGS AND DISCUSSIONS

During the course of the study, the researcher was able to gather various multi-faceted findings and observations; however, this chapter only focuses on presenting and discussing findings relevant to the commercialisation of research outputs. Hence this chapter will begin with the findings of the primary data collected from the questionnaire. Subsequently, a description of technology transfer as practiced in Malaysia will be presented. This is followed by key findings presented in the forms of issues related to technology transfer, from the perspective of various stakeholders involved. A comparison will be drawn between the findings of the secondary data obtained from Malaysia and Hungary (previously discussed in Chapter 2). Finally, this chapter will conclude with a discussion of major implications derived from the findings.

5.1 Questionnaire Findings and Analysis

5.1.1 Research Activity

The questionnaire began with the respondents being asked on the origin of collaboration for research between industry and university. 32 respondents believed that collaborative research begins within the university, while the remaining 10 selected industry for the origin of collaboration. The respondents were then asked on the source of influence for the direction for collaborative research. 26 respondents felt that such research was driven by efforts within the university, while 16 respondents indicated that the research performed was adapted to meet the needs of industry.

When asked as to whether the respondents had been personally involved in collaborative research efforts between industry and university, 16 respondents answered affirmatively. These 16 researchers were then asked to state the nature and frequency of these collaborations.

5 researchers confirmed that they had been involved in contract research activities with industry, with 2 of them confirming their participation on a regular basis. From the personal details filled in on the questionnaires by the respondents, it was noted that 4 out of the 5 researchers who disclosed their involvement in contract research were senior staff members (Professors / Associate Professors) in their respective universities.

There were 8 respondents who stated their involvement in consultancy services as a form of research collaboration. 4 of these researchers answered that their participation as consultants occurred frequently. However, when asked further on the subject, only two of them mentioned that they had set up their own consultancy firm.

8 respondents answered that they had experience in training industry employees. 4 researchers confirmed their participation as trainers on an occasional basis, while 3 researchers stated that they were called in to train industry personnel regularly. 1 researcher admitted that his experience as trainer in collaboration with industry was only limited to one occasion.

Only 5 respondents claimed to have licensed research output to industry, only 1 of these researchers stated that their involvement in licensing their research happened regularly, although 4 of the 5 researchers stated that their involvement on this level began at most two years prior to the questionnaire session. 4 researchers had applied for patents and other forms of protection for their intellectual property; however the status of their applications were still pending at the time of the questionnaire session.

The next question was on the efficiency of the units in charge of monitoring research activities within their institutions. 26 researchers felt that the research being conducted was well monitored; on the other hand, 8 researchers disagreed and believed the monitoring systems in their universities were ineffective. The remaining 8 were undecided. The respondents were then asked whether the monitoring systems in place were able to identify research was potential commercial value. 20 researchers claimed that their research monitoring units successfully identified valuable research outputs to be commercialised. However, 18 researchers claimed otherwise and a further 4 remained undecided. It was found that out of the 20 researchers who responded positively to both of the questions on the research monitoring mechanisms, 18 were from Universiti Putra Malaysia and Universiti Teknologi MARA.

The following question was on the amount of expertise and marketing skills present within the university with respect to commercializing research output. The answers given were split almost equally, as 14 researchers felt that there was sufficient expertise and skills relating to commercialisation within the university while another

13 claimed that the universities did not have the relevant capabilities. The remaining 15 respondents did not feel strongly either way.

When asked as to the existence of a monitoring mechanism for industry to keep abreast with university research developments, only 8 researchers answered positively. As in the questions regarding university research monitoring units, the response from researchers based in Universiti Putra Malaysia and Universiti Teknologi MARA researchers was positive. 7 out of these 8 researchers specifically mentioned the Research Management Centre in Universiti Putra Malaysia and the Interdisciplinary Research and Development Centre in Universiti Teknologi MARA as a means for industry to keep track of the latest research efforts.

The respondents were then asked whether current incentives to reward and stimulate collaborative research were sufficient. 28 researchers believed that the present incentive structure was enough to encourage university-industry collaborations; on the other hand, 14 researchers disagreed and gave their proposals to address the situation. The proposals included a direct increase in the amount of bonuses and incentives given, a dual pay-scale, which rewarded research efforts both inside and outside the university, and for more time to be allocated for interaction with industry.

The question was then put to the researchers as to what difficulties they had faced when obtaining funding through the IRPA funding mechanism for research. 6 researchers answered that the application that they had submitted were not within the priority or target areas set by the IRPA board. 5 researchers also reported that their proposals were considered unsatisfactory by the standards set by MOSTI.

One of the prerequisites for receiving IRPA funding is that the recipient must demonstrate that the research project will include industry participation (although this was later found to be ignored by applicants, as confirmed by a MOSTI official). It was found that 3 researchers admitted difficulties in providing evidence of linkages with industry for their project proposal. Similarly, for the IRPA grant to be justified, the proposal had to establish that project funding would be used in directly implementing research activities (as compared to construction of infrastructure, travel costs or to transfer unallocated funding for other research projects). However, 7 researchers claimed that their proposals were rejected as they had not proven that 'proper' R&D was to be performed.

Another problem faced by researchers when applying for IRPA funding was the bureaucracy in dealing with the relevant departments. 9 researchers noted that delays, miscommunication and technicalities hampered their efforts to communicate with MOSTI with regards to their research proposals. It was also reported by 3 researchers that there was inadequate feedback from MOSTI on the status of their research project applications.

In spite of these issues, 22 researchers claimed that they did not find any difficulties in obtaining IRPA grants. In addition, another 2 researchers admitted that they did not have any experience in applying for IRPA funding, and thus could not comment on these problems.

A few respondents gave suggestions for ways to improve the efficiency of the IRPA grant allocations. One of the recommendations put forward was for the current procedure of applications going though a screening process (by the university's research committee) to be scrapped, so that the research proposal would go directly to the IRPA secretariat. Another suggestion was for increased transparency on the part of the IRPA screening and coordinating committees, so that the researchers could be more aware of the status of their applications.

5.1.2 Intellectual Property

The section on intellectual property began with the respondents rating their knowledge of intellectual property. 16 researchers claimed to have substantial knowledge on the subject of IP, while13 researchers stated that they were somewhat unfamiliar with the area under discussion. Another 13 replied that they were moderately aware of the subject of intellectual property.

The respondents were then asked on their knowledge of intellectual property policies, laws and regulations within Malaysia and their institution. 23 researchers felt that they were aware of Malaysia's IP system, while 19 answered in the negative. On the other hand, 32 researchers did not have substantial knowledge of the intellectual property policies and regulations of their own universities, as compared to the 10 researchers who did. However, 18 researchers did claim to be aware of the department or persons to contact regarding IP matters within their university.

The Ministry of Education and the Public Services Department (the administration body of the civil service, which includes Malaysian university staff members) had set out a guideline regarding the distribution of income from the commercialisation of intellectual property. This guideline, entitled the Service Bill 5 (1999), is included in the IRPA manual (2001); however, only 5 out of the 42 researchers interviewed claimed to be aware of the ruling.

The respondents were then asked to state the percentage of revenue allocated to the parties involved should they decide to patent their inventions. On average, the respondents felt that it was reasonable for 70% of the revenue to be allocated to the researcher(s), and 10% each to the research sponsors, the university, and the researcher's department.

When asked on their perception of the way their universities had managed intellectual property assets generated by research, 12 researchers noted their displeasure, as compared to the 6 researchers who claimed that they were quite satisfied with the way their universities handled the management of IP assets. The majority of 24 researchers did not feel strongly either way. As with the previous questions on research activities, the positive response to the university research management was mainly from researchers based in Universiti Putra Malaysia.

The respondents were then questioned on their perception of government involvement in protecting intellectual property assets generated from university research. 22 researchers felt that IP assets from government-funded research should be patented, while 11 disagreed and 9 researchers did not take any side. In addition, when asked on the introduction of legislature to ensure government-funded research be commercialised (similar to the Bayh-Dole Act), 16 researchers agreed with such a legislation, compared to 8 researchers who felt that such a ruling was unnecessary while 18 researchers did not feel strongly either way.

The next question was on the existence of mechanisms to settle disputes regarding IP rights and ownership. Only 9 researchers were aware of such a means of dispute resolution, as compared to the 33 which were unaware. Again, most of the positive responses came from Universiti Putra Malaysia and Universiti Teknologi MARA researchers, comprising 7 of the 9 respondents.

Finally, the researchers were asked an open-ended question on the ways in which they had personally benefited from their IP rights. Four researchers stated that they had applied for patents on their research outputs, and only one researcher was in the process of setting up her own spin-off firm.

5.2 Technology Transfer in Malaysia

The transfer of technology from academia to industry can take many forms. It could be in an informal way where companies approach individual researchers to conduct research on a contract basis, for consulting, or to commercialise their findings. Presently, many local R&D institutions have formalized and promoted the commercialisation of their technology through consultancy services, collaborative and contract research projects. For the period of 1986-1995 a total of 664 contract or collaborative research agreements were conducted between private sector companies and local public R&D institutions [Md. Nor, 1996]. However, the companies which chose to collaborate with local universities were mainly multinationals, such as Intel, Dyson and Motorola, which reflects the dominance of foreign-owned manufacturers in Malaysia.

In addition, the commercialisation of research through direct technology transfer has become more focused especially in the high-technology industry, usually through technology licensing. In a conversation with a MOSTI official, it was disclosed to the researcher that for the period 1986-2003, a total of 86 technology license agreements were signed between private sector companies and local R&D institutions. More than half of these licensing agreements came from research findings from the Malaysian Palm Oil Board (MPOB). However, these figures could not be verified by other sources.

Another relatively newer and more effective way of commercializing technology is through the formation of joint-ventures and creation of new businesses. To date, 20 companies have been formed as spin-off businesses of public sector R&D institutions [MOSTI, 2005]. These companies are mostly financed by MTDC while others are established by the organisations such as the Standards and Industrial Research Institute of Malaysia (SIRIM) and MARDITECH, the venture capital arm of the Malaysian Agriculture Research and Development Institute (MARDI). These are mostly in very high-technology sectors such as in the production of vaccines, bio-diagnostic, laser equipment, specialized machinery and genetic improvement of livestock.

The average allocation for public research funding is actually relatively small to result in any kind of new products or processes. Many of the research results are product or process improvements, which in themselves are innovations nonetheless. Out of the 5,232 R&D projects conducted during the Sixth (1991 – 1995) and Seventh Malaysia Plan (1996 – 2000), only 161 received an allocation above RM 1.0 million ($263,000) [Thiruchelvam, 2004]. However, these projects have resulted in significant number of products and processes. This can be seen in the number of patents applied and pending for those technologies resulting from the research. Md. Nor [1996] provides some noteworthy examples :

(i) The laser technology and applications program undertaken by the Institut Pengajian Tinggi, Universiti Malaya, which received an allocation of RM 1.2 million ($315,000), has resulted in development of various types of lasers for different industrial applications. A patent was granted for one of the laser devices.

(ii) The research on the modification of natural rubber by Universiti Kebangsaan Malaysia, which received RM 1 million ($263,000), has also resulted in a new thermoplastic blend, which is in the process of patenting.

(iii) The multidisciplinary research on organotin chemical compounds conducted at Universiti Malaya, which has received an allocation of RM 1.2 million ($315,000), has resulted in a number of formulations, which have been granted two patents.

Apart from maximizing the return of R&D investments by the government, public R&D institutions are also encouraged to create opportunities for collaborations which would foster stronger alliances with the private sector. As such, various measures have been taken to streamline their operations and to ensure a business-oriented approach. The most popular initiative taken is to establish a 'One-Stop

Business Unit' at all public R&D institutions to handle business relationship with private sector companies and also to commercialise their respective research projects and results.

To date, only 17 out of the 33 public sector R&D institutions have established One-Stop Business Units [Thiruchelvam, 2004]. Business units like the Consultancy and Development Bureau, in Universiti Kebangsaan Malaysia, have been very active in promoting and selling services to the private sector. These business units have concentrated more on consultancy services since the return is faster and better than transferring technologies directly to the industry. Other business units include the Consultancy Unit in Universiti Malaya, the Research Creativity and Management Office in Universiti Sains Malaysia and the best-managed research management facility (according to the National Council or Scientific Research and Development) the Research Management Centre in Universiti Putra Malaysia.

Consultancy services are the main form of technology transfer conducted by these business units. However, there are many other mechanisms for the commercialisation of research and technologies developed by local universities and research institutions. Other mechanisms for the commercialisation of research can be in the form of outright sale or licensing of technology, joint-venture agreements, or start-up ventures.

The type of mechanism to be used in commercializing any particular research depends on various factors. Outright sales and licensing of technologies are only practical when they are able to attract the interest of companies which could commercialise them on a sufficiently large scale. Otherwise it would be very difficult to provide sufficient return on investments. Commercializing technology through outright sales and licensing would need more effort in promotion. Nevertheless, these forms of technology commercialisation would have minimum involvement of the universities or research institutions, once the technology has been transferred to the company.

The commercialisation of technology through the creation of new businesses or joint ventures by means of provision of venture capital funding has become more prevalent. Joint ventures and start-up ventures, although harder for local universities and research institutions, provide many advantages to them. This is advantageous to the researchers, as it provides them with the exposure and insights to the needs and requirements of the industry. Through joint ventures and start-ups, universities have the opportunity to gain a share in the growth of the company when the project is successful, instead of merely getting the royalty payments. The structure of such ventures also provides the researchers with greater control on the commercialisation process. If a technology is licensed to a big company, the technology would only be one of many projects undertaken; therefore, the attention given to the technology is of lower priority. If the technology is the sole initial activity of a joint venture or start-up company, it would enjoy higher priority and attention. It is the opinion of this researcher that the chances of success will be increased if more priority is given to the development of licensed technology as a core activity of a firm, regardless of size.

5.2.1 From R&D to Commercialisation

In order to draw useful conclusions, the process in product development will be reviewed here. A full review being out of the scope of this study, this process has been greatly simplified for the sake of brevity. At the university, research is initiated by an idea about a specific product or process. This idea is of course related to the field of specialisation of the academic institution in question as well as being in line with the research priorities of the academic.

The exact origin of this idea could be the continuation of the investigator's research or thesis, or as simple as a discussion with a colleague during a conference. The academic would then lay down a plan, and given the availability of work force and budget, a team would be put in place. This team might consist of students, or perhaps helped by technicians at the corresponding department. A first prototype allows these students to find the ways to improve overall performance, and this would enable the design of the next, improved prototype. This process of enhancing is virtually unbounded, given that generally the supervisor of the project, the generator of the idea and the coordinator would be the same person: the academic lecturer. However, this process can be interrupted many times: by the shortage of components, administrative red tape, lack of suitable students, numerous conferences and meetings. Another difficulty that could be faced is that the academic would have to play many different roles, some of which he or she might not be trained or experienced in.

In the private sector, the source of the idea is most probably product improvement (as shown by 57% of the respondents in the MASTIC survey of private sector R&D in

Fig. 4.22) which comes from the fact that the industry has to survive by selling its products, and there is usually no room for any trespassing of this rule. In large corporations however, creating R&D labs that will actively look into new technologies provides some degree of freedom, though even in this case, the research priorities are still set with the market in mind. There is a considerable difference between the way developed countries, with many big companies already in stable operation, and the developing nations, with growing industries approach the problem. Because of their financial capabilities, companies in the developed countries can make long-term investment in R&D, seeing much further ahead on the need to produce new products or improving features of existing products. Unfortunately most developing nations' companies are still struggling to be in business, bogged down with day-to-day operational and financial problems and only invest in very limited development without any degree of risk (as confirmed in Fig. 4.25). Thus, ideas and laboratory prototypes seldom attract funding from local industries.

5.3 Commercialisation and Research Management in Malaysia

Recent studies on research management practices, commercialisation and industry-public sector linkages undertaken in Malaysia revealed, among others, that successful research does not happen by chance. Instead, attention to a number of key research management practices and issues is critical in ensuring that the research effort is navigated successfully from the stage of idea-generation to adoption by the end-user.

A major problem characterizing developing countries, in general, is the prevalence of institutional and organisational fragmentation. The persistence of this problem results in increasing transaction costs, which, in turn, has the effect of diminishing prospects for a systemic approach to development based on innovation.

Prior to the mid-1980s, Malaysia did not have a formal policy for science and technology (S&T) initiatives despite its engagement in ambitious industrialisation programmes. Instead, the various agencies involved in S&T capacity building separately pursued their own agendas. This lack of coordination in policies and action plans was not without adverse consequences for the development of S&T capabilities in the country [MOSTE, 2002]. In 1986, Malaysia launched its first ever science and technology policy. But this did not help in removing the underlying problem of institutional fragmentation.

There are two major reasons for this. First, policies and strategies aimed at promoting development were based on the linear model of innovation, which failed to recognize the multiplicity of players in the innovation field and the interactions between these players in the field of knowledge sharing and knowledge production [Konstadakopulos, 1999]. Second, the problem of institutional fragmentation was not sufficiently addressed. This was because it was not considered to be a major cause for concern, while all appeared to go well with the import substitution and export promotion strategies of industrialisation and development, and factor accumulation and access to foreign technologies continued to stoke up the fire of economic growth.

The Malaysian government adopted the NIS framework in the formulation of the Second Science and Technology Plan in 2002, following the application of the national innovation system (NIS) approach to sustainable development in a growing number of countries. This represented a radical departure from the orientation of the old S&T policy (1986-2001) that was based on the conventional linear model of innovation. Even so, the Malaysian NIS is not considered robust enough to adequately tackle the institutional fragmentation problem. A major factor behind this is the overbearing nature of the social, political and economic cultures that reinforce hierarchical structures in institutional and organisational relationships. These hierarchical structures have the effect of limiting the distribution of decision-making power among institutional and organisational 'players' in the NIS framework.

They also contribute to the persistence of institutional fragmentation, resulting in a chronic mismatch between the demand for and the supply of projects, skills and technologies. The findings of this study concur with others. For example, Ali [2003] observes the weakness in the system of university-industry links in Malaysia and attributes it to a number of factors, including the dominance of foreign investments in the critical sectors of manufacturing; the weakness of the venture capital industry; and the shortage in the supply of capable research scientists and entrepreneurial skills. For Rasiah [2002], the major problem in the university-industry relationship is the failure of the education system to produce a sufficient number of skilled work force to meet the human capital requirements of industry, as in the case of the electronics clusters of Penang and the Klang Valley.

Wafa et al. [1999] found three major problems that affect industrial joint ventures in Malaysia: difficulties in obtaining high-quality inputs; integration of functional areas (for example between operation and production, and finance and purchasing); and slowness in the decision-making process. These problems essentially derive from the persistence of institutional and organisational gaps that give rise to information asymmetry, the development of a 'rent-seeking' culture and high transaction costs, which together constrain initiatives for knowledge sharing and knowledge production.

Based on the findings, it can thus be argued that the NIS and the 'triple helix' culture of the university-industry-government link [Etzkowitz, 2002] still has some way to go before the majority of technologies obtained through transfer agreements can be expected to leverage local innovative efforts. Where institutional gaps persist, technology transfer agreements stand a rare chance of success in stimulating innovation and boosting productivity growth on a sustainable basis, as is apparent from the Malaysian experience of technology transfer and economic growth [Ariff et al. 1998].

5.4 Obstacles to Effective Technology Transfer

5.4.1 Different missions

The university has a different mission to achieve from industry. From an input-output point of view, the university recruits new students and delivers graduates. University administration and procedures have been designed to cater for this need, which receives the highest priority. This model is very different in the industry. Taking the example of the manufacturing sector, the input is raw material while the output is the finished product. In this case, the focus is directed towards producing quality products, while keeping down operating expenses. Such an environment would not be conducive to R&D which requires different procedures, schedules and management.

When a research team is formed at the university, this team consists of students who are there primarily to learn. This learning process repeats itself with each batch of new students, with each project. The time consumed to learn and master the tools for the project takes a toll on the final output of the project that will be at most a "working prototype". In industry, new recruits are generally considered non-productive until they undergo a specific set of standardized training that will teach them how to efficiently use their tools. During this period, these new recruits are not expected to be productive as the company considers this period as an investment in its work force. However, these new engineers are expected to shorten as much as possible their learning curve in order to reduce the costs borne by the company.

Even when considering the production oriented and technology oriented firms, there are deep differences. A different skill set is required in managing a technology company, mainly because of the speed and uncertainty at which technology develops. Because of these different missions, the industry will seldom have access to the qualified personnel able to correctly evaluate the potential of research output. Therefore, local industry expects "complete" projects, ready for manufacturing, while academia can at most produce a "working prototype".

5.4.2 Weak communication

The lack of effective communication between academia and industry deprives both parties of vital information regarding their respective priorities and capabilities. This is evident from the MASTIC survey of private sector R&D, in which 107 firms sampled did not use universities as sources of innovation, as compared to 22 companies which rated universities and local research institutions as primary sources for innovation (as shown in Fig. 4.22). Therefore, the academic seldom knows about the actual requirements of the industry. This also explains why ideas for new projects do not emanate from industry but rather from the academic itself. Although the academic should be very well aware of the current needs of the country in terms of detailed projects, this is usually not the case. The areas of research announced by the authorities are generally too wide in scope to effectively steer a particular project. These areas have been identified bearing in mind that another step would be necessary to fine-tune the projects. On the other side, even when there is some cooperation between the two, the industry either underestimates or overestimates the capabilities of the academia with respect to practical projects. Saying that academics are unable to accurately value their own potential could equally reflect this fact. Due to this misunderstanding, a proposal for a new project has little chances of reaching an agreement. Even R&D labs with a specific mission to cater for the needs of the industry face problems when funding is concerned.

Another obstacle in the path of effective communication is the fact that the technology is usually fully imported. This characteristic hinders the task of obtaining the latest version or variant of the technology. The defiance of multinationals, for intellectual property and commercial reasons, to disclose detailed technical information to academia renders this task more complex. Perhaps the equipment provided did not come with adequate technical manuals and documentation, thus leaving the (relatively low-value) task of finding all the necessary documentation on the shoulders of the R&D team. In other cases, the equipments might be obsolete or the original manufacturer had gone out of business. The lack of communication between the concerned parties does not help creating an atmosphere of reciprocal trust neither correctly targeting the real needs of the industry.

5.4.3 Legal implications

The lack of straightforward and simple legal mechanisms for cooperation between both parties hampers collaborative activities. In general, a linkage is made between a particular company and a department at a university based on personal knowledge of people and industries. This can be perceived as a conflict of interest for the academic that is involved from both sides. Therefore, it is natural for the academic to avoid this kind of situation altogether. From the findings of the questionnaires in this study, 71% of the university researchers interviewed were not aware of IP laws and policies within their institution. Similarly, 78% of these researchers were unaware of a mechanism for resolving disputes over IP matters in their university, and these issues would only lead to a higher risk of failure should things go out of plan.

Although financial schemes for collaborative research exist, not many people (from either side) know exactly about the applicability to a specific project. Projects regarding transfer of technology differ in many ways from purchase of equipments and require a lot more expertise and patience to be judged. It is generally expected that the academic bears the burden of the heavy required paperwork. This has a very negative impact on motivating technical individuals.

5.4.4 University Supply-side Factors

One of the main obstacles to effective technology transfer in Malaysia is the lack of commercially viable projects from university research outputs. The research is dependent on the initiative of the researchers, with very little or no input from industry throughout the research process from the project proposal to presentation of the results. This is evident from the findings of the questionnaires handed to researchers, where 77% of the respondents disclosed that the origin of their research came from within their universities, as compared to 23% who took up research that they felt was more relevant to the demands of industry. However, 39% of the respondents revealed that during the course of their research they were influenced by current directions and market trends from industry, perhaps an afterthought to adapt their findings to be more relevant and marketable. Nevertheless, this "bottom-up" process minimizes chances for producing outputs which are in demand for utilisation.

While researchers have indicated that they are interested in pursuing commercial applications for their research [MOSTI, 2003], they are also bound by various institutional constraints. There are various demands placed upon academic staff, from teaching and supervising postgraduates, to conducting research and publishing findings, and to some extent administrative duties as well. The incentives and rewards mechanisms are also issues which university researchers feel the need to address, as 67% of the interview respondents felt that the current incentives were not attractive enough.

It is also relevant to note that current standards of academic benchmarking encourages research to be directed towards quality publication in internationally recognized journals and conferences instead of projects collaborated with industry. The major promotion path for an academic member of staff is to increase the number of publications. The promotion committees at universities seldom recognize practical industrial projects with usually low theoretical but high practical content. These cannot be recognized as being contributions to the knowledge base.

It takes much more effort on the part of the researchers to successfully develop a manufacturable prototype from the laboratory model because the problems to be solved are no longer confined to the specialisation discipline of the researchers, who by their nature tend to lack multi-disciplinary skills. At this stage, safety, reliability, environmental, and production costs will be important specifications on par with technical ones. For those researchers who take the challenge to tackle these issues, they are seldom given recognition, as these are not considered to have much academic value given that their work will have to be reviewed from peers within the same discipline. Thus, it is not surprising to witness that many researchers stop the research work in one area or topic after papers are published, and start another research topic.

5.4.5 Industry Demand-side Factors

From the point of view of the local industry, there are many reasons why they consider licensing research outputs from universities as a form of commercialisation that is less attractive than other forms. One reason is the state of progress of the research findings or technology is very important in the outright sale or licensing of technology. The completion of a research project depends greatly on factors like funding, scaling up, pilot plant and prototyping. Therefore the closer the technology is to completion, the more viable it is to industry. It is also worth considering whether the technology provides a partial solution to the needs of industry or should there be technological inputs from other sources. Since there is little multi-discipline and inter-institution research conducted in Malaysia, commercializing technology is usually not a very attractive option to industry.

Observations of the manufacturing sector, gained from the National Survey of Research and Development [MASTIC, 2001] revealed that there was very little cooperation between firms and universities, as recorded by 11% of the 83 firms surveyed which actually collaborated with outside parties for innovation. The manufacturing sector which is the key sector in the Malaysian economy is dominated by small and medium scale enterprises (SMEs), which make up 96% of all firms nationwide [SMIDEC, 2004]. Many of these SMEs are characterized as technology adopters, and have yet to move to a higher stage of technological advancement i.e. technology adapters. This shift is critical in moving up the value chain, and can be illustrated in the case of Korean and Taiwanese electronics manufacturers shifting from being original equipment manufacturers (OEMs) to original design or original brand manufacturers (ODMs or OBMs).

22% out of 257 Malaysian manufacturing firms which engaged in innovative activities, whether SMEs or large companies, revealed that they lacked technical expertise and personnel to successfully absorb technology into their current manufacturing process [MASTIC, 2001]. The low absorptive capacity of Malaysian firms, coupled with a lack of ability to articulate their demand in terms of product and process innovation due to short-term focus on cutting costs, is in itself is the largest factor contributing to low demand for R&D from industry.

It is not up to the SMEs alone to take up university research outputs, as multinational corporations also make up a strong presence in the local manufacturing sector, by market share alone and not by the number of firms. However, these companies have a tendency to conduct R&D and other higher value-added processes in their home countries, perhaps due to a higher-skilled workforce, tighter intellectual property regimes and logistical factors. There have also been comments from university researchers interviewed who suggest that government-controlled companies (more than 40 state-controlled public listed companies make up 35% of market capitalisation of the Kuala Lumpur stock exchange [Lopez, 2005]), should be required through legislation to source R&D and technologies from local R&D institutions. However, in light of the huge investments already made in such companies by the government, this researcher believes that researcher this would be a distortion of market forces. In addition, such government-linked companies already have their own R&D divisions, for example Petronas and Proton.

5.4.6 University – Industry Linkages

It is recognized that weak linkages between the academic world and industry is a common problem facing national innovation systems worldwide, as fundamentally these two institutions follow differing missions and practice different working cultures, with the common result of difficulties in communication. Researchers are generally found to lack understanding of industry needs and have less respect for deadlines, possibly due to willingness to excel in research by always going a little bit further.

On the other hand, the private sector by and large lacks awareness of university research capabilities, and thus tends to have unrealistic demands when dealing with academics. Private firms usually require immediate solutions to their immediate problems and are not ready to wait until the results of a particular research are available. Any idle time for the industry is translated into lost revenues and therefore should be avoided.

Another time-related shortcoming that impedes the application of academic findings towards commercialisation is the relatively longer payback time of these projects when compared to other available modes of investment. When a local industry is faced with a problem, the idea of importing the solution instead of starting cooperating with local universities seems very attractive: the solution to the problem is already available; some other competitor might have used it before so it is usually a proven technology, and the lead-time to market is much shorter.

There are also more tangible issues as compared to the ones mentioned above, which are more relevant to the Malaysian setting. Linkages between industry and academia, although growing in recent years, are still minimal. Universities are not aggressive in reaching out to industry, since funding is relatively easy to obtain from the government through IRPA grants, which was confirmed by 53% of university researchers surveyed who had experience in applying for IRPA funding. This may explain why only 17% of total research funding for universities are derived from non-public sources [MASTIC, 2004]

Although self-financing targets for public research institutions and universities (30% and 15% respectively) have been identified in the Second Science and Technology Policy [MOSTI, 2002], the realisation of this measure has not been undertaken due to weak implementation capacity of the policy. As a consequence of this heavy dependence on IRPA funding, long-term relationships have not been established between industry and these research performing organisations.

While it is clearly stated in the IRPA guidelines [MOSTI, 2001] that all approved projects should involve more than one institution, or at least demonstrate industry linkages, in practice this guideline is often ignored. This was shared in an interview with a MOSTI official in charge of disbursement of IRPA funds, and in addition 7% of researchers interviewed for this study claimed that their IRPA applications were denied due to a lack of evidence of industry linkage. Another problem was that applications were usually not within priority or target areas (as stated by 14% of the researchers interviewed), or the research design was flawed to begin with. There was also a significant lack of marketing knowledge in the research proposals, with insufficient market analysis being conducted and thus reducing the chances of being approved for funding. The official stated that 51% of prioritized research proposals and 40% of strategic research proposals were rejected, in part due to the reasons stated above, as well as failure to show linkages with either industry or other research institutions. The worst cases would be from the 16% of researchers who were interviewed, as their proposals which did not suggest any R&D element whatsoever. It was claimed by the MOSTI official that these kinds of applications were made only to gain funding for purchasing equipment, or to conduct surveys. The official revealed that it was due to this lack of confidence in research conducted in public universities that MOSTI was considering opening up IRPA funding to private universities with established postgraduate research facilities.

33% of the interviewed researchers claimed that there were no attractive incentives offered for researchers to collaborate with industry. Also, researchers themselves perceive that working with industry is 'second class' compared to academic research. Industry has very little confidence in the ability of universities to address their problems due to a number of factors including poor adherence to tight timelines by university personnel as well as lack of customer-service mentality among universities. Industry expects local research institutions to guide local firms long after the research findings have been transferred.

Industry does not require sophisticated technologies but, instead, simple adaptations or improvements to existing processes. Universities fail to address these needs and are also poor at promoting their research findings in terms that industry best comprehend - that is, cost savings or increased profits/sales.

University researchers are bound by inflexible rules and procedures inhibiting their mobility and involvement with companies outside the university structure. The relevant technology transfer offices within universities are still in their early stages of operations, and their role as conduits to industry will remain limited for the short term. Only 33% of interview respondents felt that there was sufficient expertise in business development and marketing personnel related to technology transfer within their universities, concurring with the findings from the survey conducted by the Business Development Unit of MOSTI [2003].

This shows that there is an urgent need to upgrade the skill sets of these personnel in the areas of technology valuation, business plan development, market research and assessment, negotiation agreements and basically technology transfer management as a whole. However, the researchers themselves need to advance their skills in specialized engineering and development, specific to achieving the level of scaling-up and producing prototypes of their research outputs, as this stage is still the responsibility of the researchers, before industry is satisfied with what they have been presented with and eventually taking up the outputs for commercialisation.

5.4.7 Intellectual Property Rights

The researcher was fortunate to be able to conduct an interview with a senior MIPC official, in their headquarters in Kuala Lumpur. The official explained that MIPC was in the process of expanding their operations. MIPC was also in the process of conducting a recruitment drive, with heavy emphasis on attracting fresh graduates through the Malaysian civil service website as well as the mass media. It was interesting to note that while openings for patent officers made up a big portion of positions offered in the civil service website, the highest employment offers were for the enforcement arm of the Ministry of Domestic Trade and Consumer Affairs. While not directly under the jurisdiction of MIPC, these employment officers are usually ordered to raid illegal hawker stands selling pirated copies of movies and software.

In 2003, MIPC revealed that there was a backlog of more than 15,000 patent applications, which had apparently been building up for a few years [APAA, 2003]. The official replied that the backlog was in the process of being cleared up, and the situation would be under control once more patent officers were hired (However as of April 2005 the backlog had increased to 24,750 [Krishnamoorthy, 2005]). On the lack of IP awareness in Malaysia, the official agreed that more should be done to educate the public on the importance of IP rights, and that MIPC was in the process of conducting road shows and exhibitions highlighting successful utilisation of IP. However, she did note that more emphasis was being given to educating the public and industry, and she admitted that there had not been much contact made with public sector researchers. The official also confided that Malaysia should be fully compliant with the Patent Co-operation Treaty by the end of 2005, and that more initiatives to encourage IP protection were in the pipeline. One suggestion is the implementation of a proposal made during the 2004 National Budget, where the cost of IP protection by public sector researchers would be fully borne by the government.

5.4.8 Research Management and Funding

Adoption of sound research management practices is central towards enhancing utilisation of research. Such practices help to reduce uncertainties surrounding the implementation of a research project. The studies revealed the importance of adhering to a number of management practices such as ensuring focused research; initiating preparatory activities prior to the research proper; provision of adequate funding; provision of demonstration facilities; forging linkages; developing marketing activities; sensitivity to non-technical factors; swiftness to market; research leadership and commitment; and adoption of a holistic approach to research utilisation.

There are wide disparities in the adoption of sound research management practices among universities despite being subjected to similar external funding environment and civil service regulations. These disparities are a reflection of varying top management's commitment to the research effort in these organisations as well as being a consequence of the deficiencies in the national public research funding mechanism. For example, 47% of the researchers interviewed for this study (20 out of 42) were satisfied with the way their universities managed research activities. Out of these 20 researchers, 18 were from two universities,namely Universiti Putra Malaysia and Universiti Teknologi MARA .

Lack of regular research assessment exercise has led to disparities as described above. Such exercises are critical to demonstrate to fund-receiving bodies that the government is serious about the effectiveness of research spending. Absence of measures such as research audit to keep universities on constant alert in terms of adoption of proper management practices would only promote weak research performance.

The research process in universities is characterized by a linear approach whereby research projects are largely initiated by researchers and implemented in a sequential manner without addressing the end-user's requirements until the projects is about to be transferred to the end-user. Industry participation in many of these projects is minimal.

Although separate business units have been established in almost all the universities to support commercialisation efforts, such units have, in most cases, been not effective due to funding difficulties as well as lacking the appropriate skills to perform this function competently. Accordingly, efforts to reach out to industry and other potential clients have not been aggressive.

While there are sufficient venture capital funds in the system, the bulk of finance is still at the expansion growth and IPO stages. There is still a paucity of seed capital in the financial system [Bank Negara Malaysia, 2003]. The narrow focus in research funding under the national public research funding mechanism has undermined the potentials of several research projects undertaken by universities. Funding is only provided to cover the core research aspects of the project and not its subsequent related activities that are crucial in transforming it to a form readily adopted by the end-user. Also, funding for pre-technical, prototype construction, design/engineering, technical extension and marketing activities undertaken by universities are not provided. This gap in funding has resulted in most of the output especially from the universities to be at a stage where further development work is required before they can be adopted by industry. Furthermore, membership into networks or activities aimed at strengthening networks is not funded.

Seeking research funding or incentives involves transactions with numerous government agencies. Industry has suggested that these incentives be streamlined and easy to access, for example, leadership and commitment from top management are essential in ensuring that systems and structures that are established to enhance the research utilisation process are made to work for the organisation. Most, if not all, universities under study boast of impressive screening, selection and monitoring systems. However, the implementation of these systems in many universities has been unsatisfactory. In addition, research projects undertaken by universities are generally not linked to any strategic agenda. Accordingly, projects that are funded are widely diffused across a broad range of research areas and do not lead to a consolidation in the development of particular set of capabilities.

5.4.9 Governance

Universities are constrained by civil service regulations from adopting more effective research management practices to enhance their research efforts. For example, researchers are not provided with the flexibility and resources to make quick decisions on administrative, financial or personnel matters.

Senior appointments in universities do not reflect importance of commercialisation activity. Presently, there is no separate Deputy Vice-Chancellor appointed for commercialisation, unlike similar appointments for academic research, student affairs and development. This absence undermines the performance of public universities in developing and sustaining linkages with industry;

In contrast to universities, public research institutions that have performed well (in terms of technology transfer) owe their success largely due to strong industry participation in their operations right from the outset of their establishment. They are essentially industry-specific research organisations, and thus there is no clear policy in terms of intellectual property rights (IPR) ownership as well as on spin-outs.

5.5 Comparative analysis between Malaysia and Hungary

As mentioned previously in Chapter 2.6, the national innovation system of Hungary was examined because of the common factors between Malaysia and Hungary. It would be relevant to compare R&D indicators to see how far these countries have progressed in building upon their innovative capacity.

5.5.1 R&D Inputs

Figure 5.1 shows the amount spent on research by Malaysia and Hungary, as well as their relative ratios to the GDP. It can be seen that Malaysia spends much less than Hungary on R&D, and since 1994 the amount spent by Malaysia was less than halfnh of Hungary's expenditure. Similarly, Hungary allocates more R&D expenditure per GDP compared to Malaysia, although the difference between the two nations has narrowed in recent years.

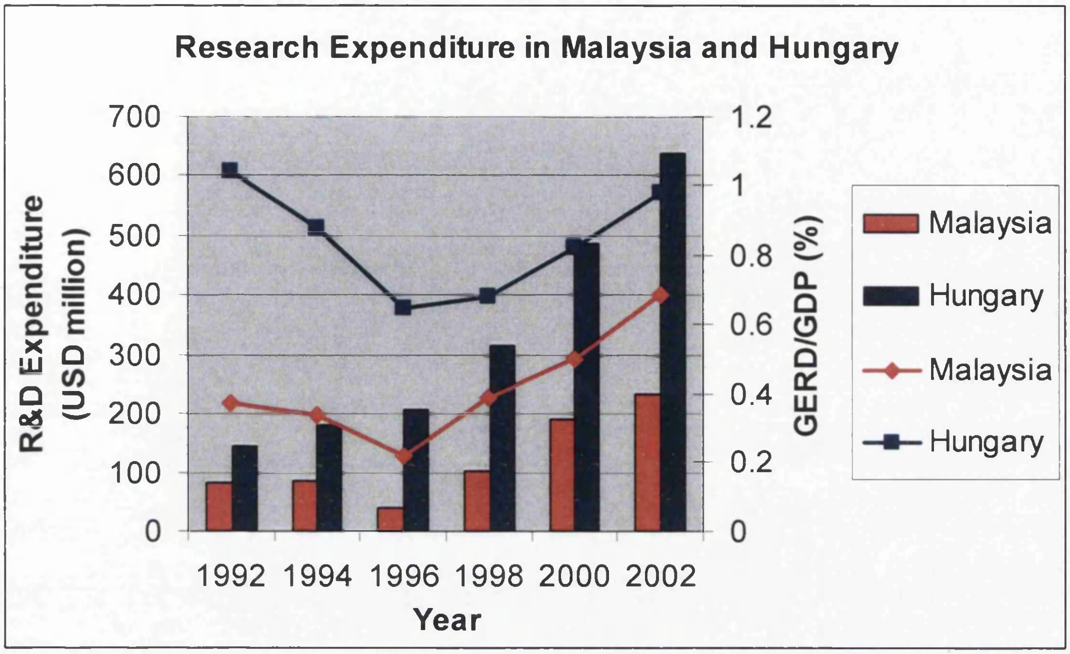


Figure 5.1 – Research Expenditure in Malaysia and Hungary [MASTIC, 2004; HCSO, 2004]

Further analysis of the figures shows that while Hungary has consistently increased its research expenditure, Malaysia experienced a deficit in R&D expenditure in 1996. The figures for GERD / GDP show a slightly different trend, with both countries experiencing a drop from 1992 to 1996, before increasing at a fairly constant rate. However, from 1992 to 1994 the GERD ratio for Hungary dropped by 0.4%, while Malaysia experienced a reduction of 0.15%. Similarly, the figures for 2002 show that Malaysia managed to record a ratio of 0.7% (a threefold increase from 1996), while Hungary reached 0.98% from 0.65% in 1996. It would seem that 1996 was a transition year for both economies, with the shift to privatisation in the case of Hungary and the onset of the regional financial crisis in Malaysia. Previous sections have discussed how these two nations developed various S&T policies in response to these situations, and from the GERD ratios the relative success of these policies in prioritising R&D can be seen.

The other measure of R&D input that has been examined is human resources, in this case presented in Figure 5.2 by the number of full-time R&D personnel. Malaysia's workforce at 10 million people is twice that of Hungary (4.8 million) [CIA, 2005], although researchers make up more of the workforce in Hungary. There was no significant change in the number of R&D personnel in Hungary, with an average of 22,000 from 1992 to 2002. In the case of Malaysia, the number of R&D personnel averaged 9,984 from 1992 to 1998, before increasing sharply to around 25,000 in 2000 and 2002. The figures for these two years show that the number of researchers in the two countries are almost equal, although the share of Hungarian researchers out of the total workforce is more than twice compared to their Malaysian counterparts.

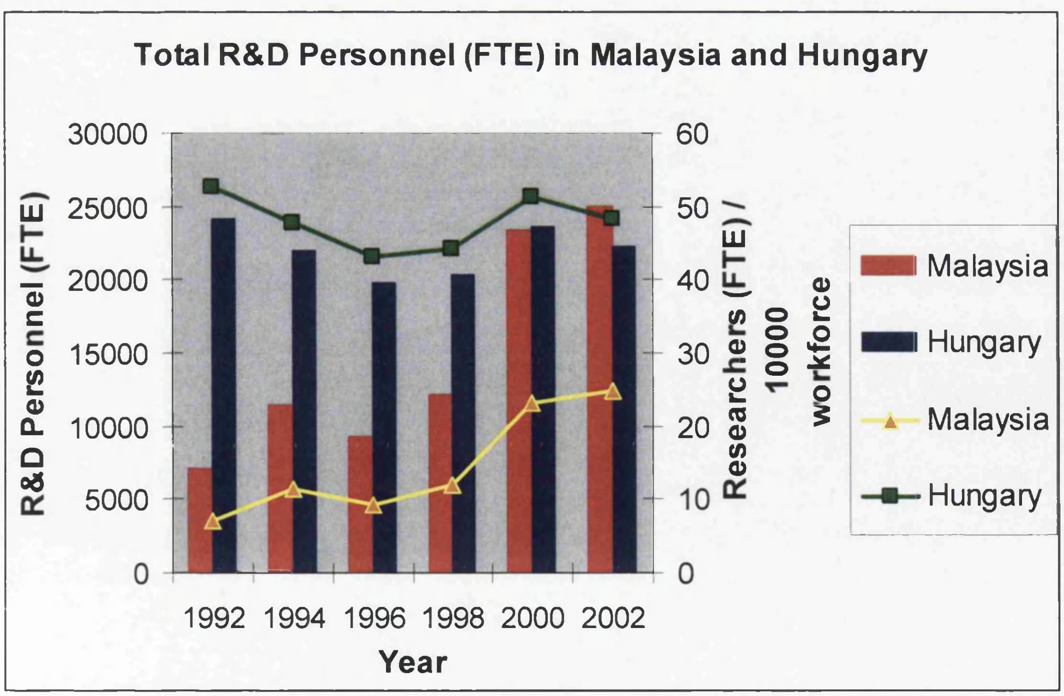


Figure 5.2 – Total R&D Personnel (Full-time equivalent) in Malaysia and Hungary [MASTIC, 2004; HCSO, 2004]

The sharp rise of the number of R&D personnel in Malaysia (which can also be seen in Figure 4.14) could be attributed to the increase in universities and colleges caused by amendments in the Universities and Colleges Act. In the case of Hungary, while previous discussions have shown that researchers were affected by the wave of privatisation from 1992 to 1996, they maintained mobility in the sense that industry researchers who were dismissed by streamlining exercises managed to gain employment in the public sector. It would also be interesting to note that Malaysia's population was growing at 1.8% in 2004, while Hungary was experiencing negative growth at -0.26% [CIA, 2005]. Therefore if current conditions persist, Malaysia would have a chance of reaching the same number of researchers per workforce as Hungary in five to ten years time.

5.5.2 R&D Outputs

One of the R&D outputs to be used for comparison between Malaysia and Hungary are the measure of patents granted. Since patent systems are different between countries, the US patent system will be used as a benchmark. From Figure 5.3, it can be seen that Hungary significantly outperforms Malaysia in the number of US patents granted, except in 2000 when Malaysia led Hungary by 3 patents.

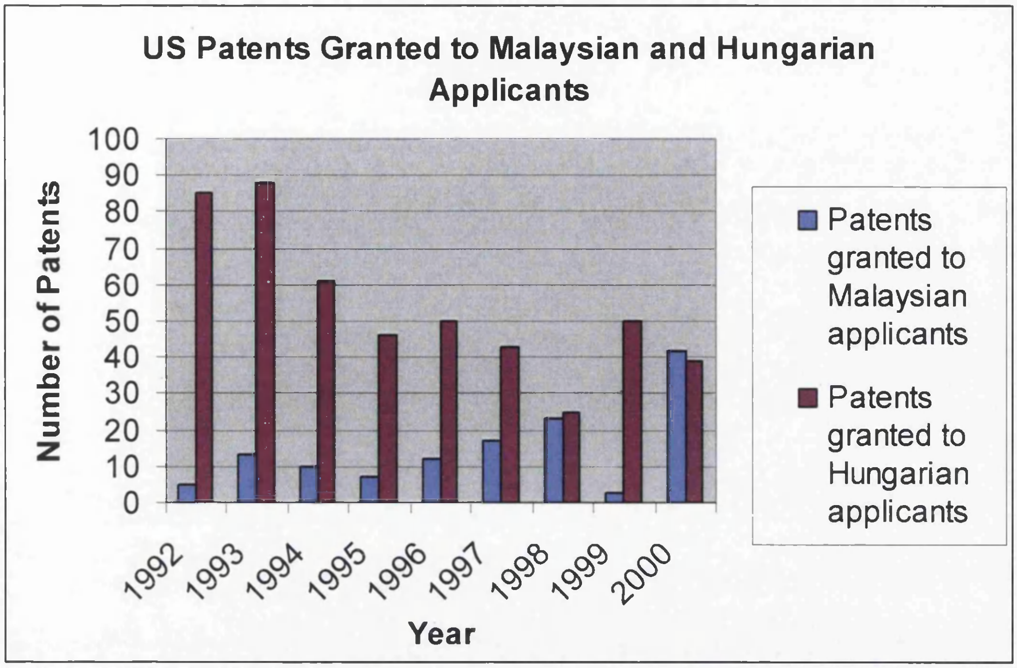


Figure 5.3 – US Patents granted to Malaysian and Hungarian applicants [USPTO, 2003]

There was an increasing trend in patents granted to Malaysian applicant from 1995 to 2002, except for a drop in 1999. This was not the case for Hungary, which showed a decreasing trend, especially from 1993 to 1998. Since these figures include patents applied by companies, it might not be relevant to normalise patents per unit of population. However, from 1992 to 2000 the number of patents granted to Hungarian applicants outnumbered Malaysian applications by almost 4 to 1, which means the population difference between the two countries still would not make up for the poor record of Malaysian patent applications in the US.

Figure 5.4 shows the final measure of comparison between the national innovation systems of the two countries, which is the high-tech manufacturing sector and the share of its exports from the national total exports. Malaysia has a strong presence in electronic exports, and this is the main factor in explaining the strong performance in high-tech exports. The value of Malaysian high-tech exports has grown from US$ 22 billion in 1992 to US$ 60 billion in 1997, before reaching a peak of US$ 74 billion in 2000. Hungary, on the other hand, showed relatively poor export figures, with pre-1996 values at around US$ 1 billion and peaking at US$ 8.5 billion in 2000.

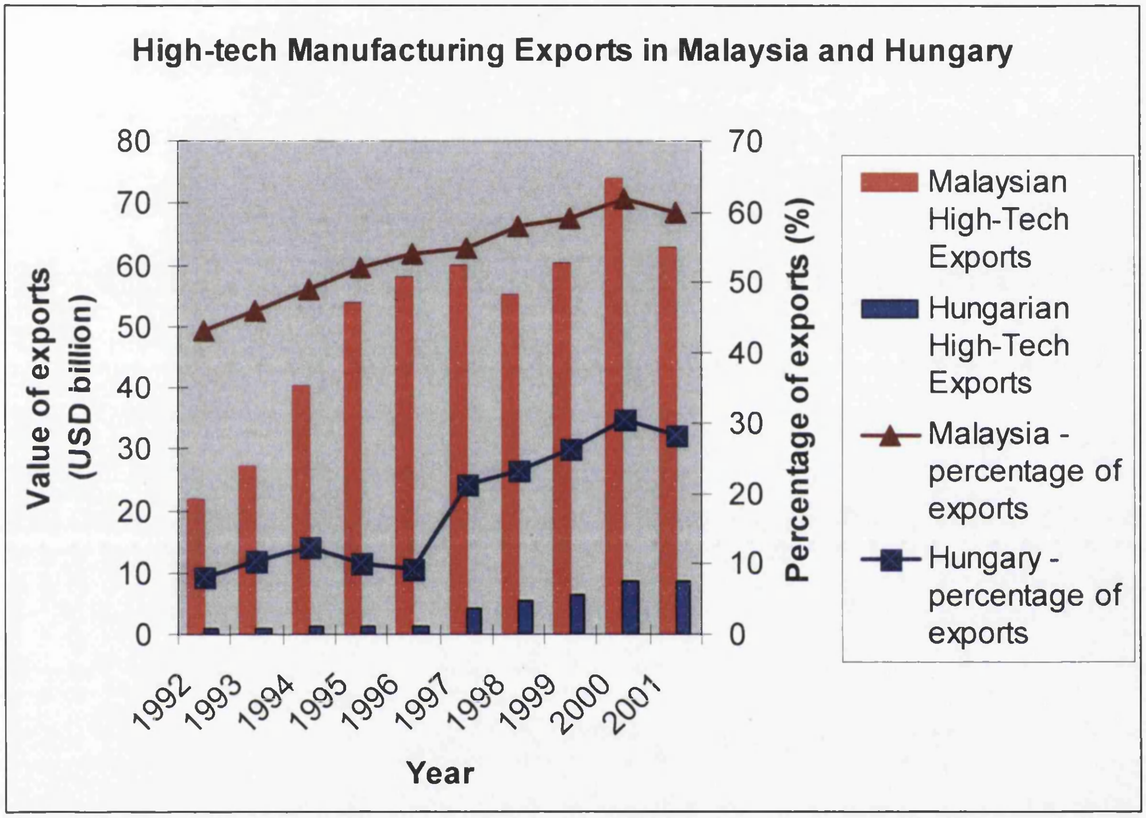


Figure 5.4 – Value and share of high-tech manufacturing exports in Malaysia and Hungary [OECD, 2004; Mani, 2004]

The significance of the high-tech manufacturing sector to Malaysia's economy can be seen by the consistently majority share that high-tech exports contribute to Malaysia's total exports. The share of exports grew from 43% in 1992 to 62% in 2000, compared to 8% and 30% respectively for Hungary, although it can be seen that the rate of growth for these figures are almost the same. It would be relevant to note the strong presence of multinational corporations in the manufacturing sectors of both countries, which were established during the FDI-led boom of the 1980s.

It can be concluded that although Malaysia shares some common factors with Hungary, there are certain factors which can be seen as strong points in Malaysia's favour. Research expenditure has continued to increase, and at current rates the GERD ratio should meet the targets (1.5% of GDP) set in the National Science and Technology Program II (STEP2). The manufacturing sector remains a valuable asset, and the large share of high-tech exports is vital to ensure a strong foundation for R&D and innovation to thrive. However, there is room for improvement in human resources, as Malaysia's current percentage of researchers out of the total workforce is low compared to Hungary. More researchers, scientists and engineers should be hired to meet the STEP2 targets (60 R&D personnel out of 10,000 population) by 2010. Malaysian researchers and inventors should also take advantage of their intellectual property by applying for patents locally and abroad, as the state of IP protection in Malaysia is poor compared to countries with smaller populations like Hungary.

5.6 Implications of Findings

A number of managerial and policy implications emerge from the above findings as follows:

i) Successful research commercialisation is essentially a process issue. Disciplined research management and top management commitment are crucial in ensuring that sound research management practices are being effectively implemented in an organisation. Failure to exercise such discipline and commitment would result in the indifferent adoption of these practices as evident in many universities.

ii) Adoption of a holistic approach to research utilisation in universities would have implications on the funding of projects since all activities from the stage of preparatory studies to marketing of the research findings as well as provision of technical services should be supported. Also, inputs from all the parties involved in the project including the end-user must be actively sought prior to the implementation of the project.

iii) The weaknesses in the national public research funding mechanism (specifically IRPA), for example, the absence on adoption of sound management practices as a condition for funding and the lack on enforcement on requirements for industry collaborations - have failed to impress upon most of the universities on the need to adopt sound research management practices. Universities are unable to implement more responsive research management practices due to the need to adhere to civil service regulations. Such regulations have impeded their ability to take quick decisions as well as to initiate actions designed to enhance their research efforts.

iv) Building relationships and trust is central to any research effort, particularly in a developing country environment where level of technological competence among firms is low. A more service-oriented approach is needed if universities are to reach out to industry in order to build credibility and trust.

However, such an approach will be enhanced by personnel, institutional and funding policies that promote such linkages.

The above managerial and policy implications suggest that changes are necessary in the way public R&D is being organized and funded in Malaysia. These changes are essential so that the results of public R&D can contribute towards the acquisition and strengthening of the nation's technological capabilities. Such efforts would be aided by a public R&D enterprise that fosters institutional flexibility and creativity besides promoting a culture of sound research management practices underpinned by relevance, quality and partnership.

As these characteristics are absent in most universities, institutional reforms as suggested by Intarakumnerd *et al* [2002] in the case of Thailand, are in order if Malaysia's national innovation system is to evolve into a more dynamic and connected system. Such reforms will have to take cognisant of the local nuances among public research institutions, academia and industry as emphasized by Hall *et al* [2001] and need not be mere transplants of what has been developed in other countries.

6.0 CHAPTER VI – CONCLUSION AND RECOMMENDATIONS

As outlined in Chapter I, the aim of this study was to explore the process of technology transfer from Malaysian public universities to the private sector. A summary of the major conclusions derived from the findings of this study will be presented. This chapter will then position the significance of the study within the existing body of knowledge. Limitations present during the process of conducting this study, whether self-imposed or circumstantial shall also be highlighted, and the chapter shall conclude with recommendations based on the findings and areas for future study.

6.1 Conclusions of Study

The study has specifically concluded that:

- university researchers have developed increased awareness and understanding of the commercial viability of their research output (only 30% of the researchers surveyed claimed that they were unaware of the importance of intellectual property). Some are even taking their first steps towards protecting their intellectual property by patenting their findings, hence resulting in more vibrant research activity in the Malaysian public universities;

- the Malaysian government is fully supportive of university-industry research collaborations, although there still remains a perception that the government is still not doing enough;
- the frequency of institutional and organisational fragmentation is still a problem, as many agencies are competing for similar research funds and authority;
- industry is not inclined to take up research output from university, as there is still a perceived lack of relevance to their bottom line;
- there is a low level of technology absorption among Malaysian firms, resulting in inadequate innovative activities in the private sector;
- the lack of private venture capital firms has resulted in the government establishing several venture capital funds, managed by civil servants;
- Malaysia should definitely improve its intellectual property protection regime, as this is a major factor in determining of the success of knowledge transfer within a knowledge-based economy;
- the Malaysian national innovation system shows potential, and on the basis of R&D efficiency can compete with nations like Hungary
- on a national level, there are simply not enough researchers, scientists and engineers to develop an effective science and technology manpower base.

6.2 Significance of Study

This study is intended to explore and present a current overview of the state of technology transfer activities within the Malaysian national innovation system, in line with the shift towards a knowledge-based economy. This decision was made due to the fact that as of the present moment, there are few systematic studies published on the national innovation system of Malaysia as a whole, and even fewer specifically on the process of technology transfer within a Malaysian context. The generation of research and its movement from one organisational setting to another necessitates proper management of knowledge, and given Malaysia and other nations' steps towards a knowledge-based economy it is logical to frame this study within that perspective. Thus, a study such as this is timely for Malaysia in its current state and interest in looking at the commercialisation potential of research output not only from traditional applied scientific research, but also from agro-based research and biotechnology, where Malaysia's biodiversity is recognized as a competitive advantage.

Previous studies related to the topic of technology transfer in Malaysia have focused on the lack of proper research management, the effectiveness of government policies, and on venture capital funding. These studies, and others, mainly concentrate on individual instances, or on specific industries and sectors. This study has tried to present a broader view of the situation, taking into account involvement from the government, academia and the private sector. It is through this attempt of exploring the setting at a more holistic level that this study is meant to be viewed and placed within the existing body of knowledge.

The Malaysian national innovation system is characterized with some amount of overlap between the roles of the government, universities and industry, similar to many developed as well as developing nations. As mentioned in Chapter 2.4, the American system is characterized with autonomous and largely independent institutions, while the Russian model is defined by close linkages between public and private sectors dominated by the state. However, the findings from this study indicate that Malaysia's national innovation system is primarily driven by the government, with the main objective to increase linkages between universities and industry. Compared to the American or Russian system, there are common aspects that Malaysia shares with other developing nations, therefore it is hoped that the findings of this study would be more appropriate for researchers of national innovation systems in developing nations.

6.3 Limitations of Study

Since the study had to be carried out in the Malaysian setting, it meant that the researcher had to travel from Wales to Malaysia at some point during the course of the research. This in itself proved to be a major limiting factor, as preparations for collecting data had to be arranged beforehand; it was not easy to return to correct or confirm findings. However this was anticipated in advance, and similar work carried out by the Knowledge Economy Research Group at the University of Wales Swansea turned out to be most valuable in drafting suitable questionnaires to be distributed.

The main limitation however was in the sampling for primary data collection through semi-structured interview questionnaires. With such a short time frame, it was decided early on that the most strategic way to locate academic staff who had experience in research and were willing to be interviewed would be to find occasions where there would be a mass of such researchers. As mentioned in Chapter III there was a rising trend of research exhibitions and conferences related to innovation and university-industry collaborations, therefore the researcher made an effort to attend as many related events as possible and conduct formal as well as informal interviews and have discussions with the participants. Such events also provided opportunities to observe first-hand the quality and quantity of research activity and output in Malaysia.

However the nature of some of these events did not allow much time for interaction outside the formal activities planned by the event organizers, and at times some lead researchers were not present at their booths to talk about their findings, leaving such duties to their graduate students who were unprepared or unable to answer the questionnaires, especially in the areas of research management, funding, and intellectual property. This lack of access to data proved to be a constraint in the gathering of questionnaires, as some questionnaire forms had to be discarded due to lack of sufficient responses.

It was also the researcher's decision to self-administer the questionnaires, as compared to handing them out and collecting the completed forms later. While this ensured the respondents understood the questions better, as well as achieving a higher return rate, more time had to taken and this issue could have been better addressed. In the later stages of gathering data, this was partly rectified by distributing the questionnaires to the researchers in small groups, with the supervision of the researcher in case there were any queries.

One pertinent point is that the events that were attended, especially the exhibitions related to university-industry collaborations, were meant for researchers to present and market their findings, and to some extent their universities as well. It is of the researcher's opinion that during the course of answering the questionnaires, some academics might understandably be influenced to express slightly more positive impressions of themselves and their universities. In fact one senior academic privately confided that he shared the same opinion of this "mission to promote self and university". While this attitude did not manifest itself greatly within the answers provided on the questionnaires, perhaps a more neutral choice of venue and setting would be appropriate to improve reliability of the data.

Interviews conducted with government staff and members of industry did not present themselves with similar problems, as in most cases the researcher was fortunate to be directed to the relevant person in charge, or in the case of industry, key personnel directly involved in technology development. Arrangements for meetings were made beforehand, with the issue to be discussed already notified. However the majority of such interviews were one-on-one meetings, with only one viewpoint from each organisation because of restricted time on the part of both parties. A wider spectrum of perspectives on the state of affairs could have been gathered if interviews were conducted at different levels of the organisation, for example the views gathered from the perspective of the senior administration or policymakers would be interesting to compare with interviews conducted with members of staff at the executive level.

Another limitation came from the lack of funding to collect data, as the researcher was self-funded and had to consider financial constraints in traveling. Combined with the time restrictions mentioned above, this meant that visits arranged to certain universities, incubators and company headquarters located far from the capital city Kuala Lumpur had to be cancelled. As such the operational capabilities of those institutions and organisations with regard to technology transfer could not be properly assessed, therefore some of the findings related to these universities and incubators had to be sourced from secondary data such as publications, websites and press reports.

6.4 Recommendations

Enhancing research management demands unflinching commitment and leadership on the part of top management. Such efforts must be sustained and institutionalized lest organisations drift. These efforts would also be aided by an external environment which fosters the adoption of good management practices. This study submits some suggestions towards strengthening the research management of universities as follows:

i) Improve Research Funding Mechanisms

The perception that IRPA funding is relatively easy to obtain, if left unchecked, may lead to indifference towards adopting sound research management practices since funding is seen not to be competitive. Given limited financial resources, it is vital that IRPA adopt strict guidelines in funding research projects. In the case of applied projects, only proposals that come with industry participation or are specifically addressed to solve industry problems would be considered for funding. Such a condition would ensure that partnerships with industry are encouraged. Such stringent requirements would ensure that management in universities re-orientate their research activities as well as adopt tighter project management practices. However, there is still a need for a similar funding mechanism tailored towards 'blue sky' or basic research to be planned and implemented.

ii) Initiate Research Management Benchmarking Exercises

The uneven research management practices among the universities, would, if left unchecked, have serious consequences on public sector R&D as a whole. Not only will scarce financial resources be wasted but more promising projects proposed by the better managed organisations may go unsupported. It is suggested here that a research management benchmarking exercise be commissioned to gauge performance of fund recipient organisations according to standard research management practice. A research management league table can be prepared following this benchmarking exercise, and organisations which continue to fare badly will find their funding support levels progressively reduced. Such an exercise would send a powerful message to the universities to be fully committed to the research effort in their respective organisations lest they risk having funding levels drastically trimmed. Such an exercise will also inform policy-makers on how well investments in research are being expended.

iii) Expand the scope of IRPA funding

The present narrow scope of activities funded under IRPA, as evident from the case studies, should be expanded to include activities like development, up-scaling, engineering and testing of research findings. Such activities are crucial in order to establish the parameters of utilisation by the end-user. Also, preliminary technical activities are vital in reducing uncertainties surrounding a research project and should be supported. Additionally, funding should be provided to assist the marketing activities of the Business Units of universities as well as promoting industrial technical extension activities. IRPA funding should also be expanded to cover partnerships with Malaysian and foreign scientists abroad.

iv) Separate funding for promoting linkages and pre-seed development

There is a pressing need for decentralisation of research funding in order to promote responsiveness among universities. Although universities are presently provided with separate allocations for institutional funding, this is not sufficient to enable them to forge preliminary linkages with industry or to fund interesting ideas from the seed level.

v) Promote Autonomous Operations of Universities

Much has been said about the constraints faced by universities in adopting more effective management practices due to the rigidities imposed by the need to adhere to civil service regulations. It is imperative that universities be granted greater autonomy to set their own administrative, personnel and financial procedures and conditions if they are to succeed in an operating environment where partnerships are crucial. Such autonomy can be achieved, for example, through administrative or statutory means. Whatever the route, such autonomy would ensure that universities are able to take decisions quickly; engage in activities designed to enhance the utilisation of their research findings; review their institutional structure so as to be more focused, less bureaucratic and more client-oriented; and introduce more appropriate remuneration schemes for recruiting as well as rewarding staff.

vi) Improve Fiscal Incentives for Industry

In the face of emerging competitive threats from other developing countries, Malaysian firms should upgrade their indigenous capabilities and shift their emphasis from labour-intensive mature technologies to more knowledge-intensive technologies. However many firms are understandably more concerned with short-term profits than introducing new or improved products or processes. As the study has shown, there is a dire need for the private sector to increase their technology absorptive capacity. There are already several fiscal incentives related to research and development offered by the government. Perhaps tax incentives specific to encourage industry to undertake activities such as reverse-engineering and other higher value-added processes would be beneficial.

The recommendations of this study could provide added perspective to various stakeholders in university-industry research collaborations, such as policymakers from relevant ministries, university staff, and venture capitalists, in their combined efforts towards building a mature and more structured Malaysian national innovation system.

6.5 Future Work

In the same way as this study builds on the work of others, it is hoped that in the future other researchers will carry on from where this study ends. This is especially important in the case of national innovation systems of developing countries, where the growing lack of natural resources and the increasing value of intellectual and human capital as economic factors necessitates different ways of viewing research from universities as a valuable resource on its own, to be leveraged to increase competitiveness.

As nations around the world shift from present labour-based and production intensive modes of economy to a knowledge-based economy, there is a need to examine the production and dissemination of knowledge. Similarly, there is also a need to analyse the effectiveness of the utilisation of such knowledge in gaining competitive advantages, in the same way as numerous management-based studies have been conducted on the efficiency of capital and labour usage. With this study and others in context, perhaps opportunities will arise for carrying out research on measuring quantifiable knowledge outputs and deliverables specific to the Malaysian national innovation system, in the broader perspective of a knowledge-based economy.

One aspect of the Malaysian national innovation system that was not investigated in depth in this study is the role of industry-specific public research institutions, as it was decided that these institutions fell outside the scope of this study, which was limited to public universities. Examples of these public research institutions include the Rubber Research Institute of Malaysia, Malaysian Agriculture Research & Development Institute, and Malaysian Institute of Nuclear Technology. As these research institutions have specific missions, and perform very few activities besides applied research, they can concentrate on their core activities and in fact have achieved various degrees of success in commercializing their research output. There is much to learn from the practices of such institutions in taking their research to market, especially since public research institutions and universities have many features in common such as highly trained personnel, access to public funding, and limitations in operating as quasi-governmental organisations. It would be interesting to see if future research uncovers parallels between universities and research institutions and areas for cooperation, as well as lessons to be learned from both institutions towards effective transfer of technology.

Similarly, the role of industry within the Malaysian national innovation system was not given enough attention in this study, as there was little data collected on the subject, as well as a very low rate of adoption of university research outputs. This lack of focus on industry was also reflected in other academic studies as well as those conducted by public sector policymakers. Perhaps it would relevant and timely to investigate what can be done to increase demand for university research from the perspective of industry, as it would be somewhat unproductive to improve knowledge generating and distributing capacity of universities without successful take-up from industries.

As mentioned in Chapter 5, the frequency of institutional and organisational fragmentation is a common problem not just in the case of Malaysia but with many other developing nations. It is with this in mind that the study is also designed to focus on the roles and linkages between the different organisations involved in technology transfer, instead of measuring quantifiable outputs of patents and products. Perhaps in the future when there are sufficient numbers of research collaborations between universities and industry and likewise plenty of commercially viable research outputs, a more quantitative review would be more revealing of the exact situation.

Finally, it is hoped that in due time the effects of recent science and technology policy measures put in place by the Malaysian government can be evaluated and the performance of the national innovation system can then be assessed, possibly taking into consideration the findings in this study.

Bibliography

Adeboye, T. (1998) “Africa”. *World Science Report.* Paris, UNESCO

Ali, A. (2003) *Engaging Economic Development through the Commercialisation of Research: the Malaysian Experience.* Paper presented at the General Conference of the Association of Commonwealth Universities 2003, Belfast.

Amabile, T.M. (1996) *Creativity in context.* New York, Westview Press

APAA (2003) “*Patents Committee: Country Report for Malaysia*” Report prepared for 13th General Assembly of Asian Patent Attorneys Association, B. Thompson (ed.). October 2003, Kota Kinabalu, Malaysia.

Ariff, M., M. H. Piei, et al. (1998) *Responding To The Economic Crisis In Malaysia: A Pro-Human Development Perspective*, United Nations Development Programme Regional Bureau for Asia and the Pacific.

Arthur, W. B. (1998) "Increasing returns and new world of business." *Harvard Business Review,* Vol. 74(4) pp. 100-109.

Audretch, D.B. and Stephan P., (1996) “Company-Scientist Locational Links: the case of Biotechnology”. *American Economic Review*, Vol. 86(3) pp. 641-652.

AUTM (2004) AUTM Licensing Survey: FY 2003 - A Survey of Technology Licensing (and Related) Performance for U.S. and Canadian Academic and Non-profit Institutions and Technology Investment Firms. A. J. Stevens and F. Toneguzzo, (eds.) Association of University Technology Managers.

Balzat, M. and H. Hanusch (2004) "Recent Trends in the Research on National Innovation Systems." *Journal of Evolutionary Economics* 14(2): 197-210.

Bank Negara Malaysia (2003) "*National Bank of Malaysia - Annual Report 2002*". Kuala Lumpur, Bank Negara Malaysia

Bidault, F., and Fischer W .A., (1994) "Technology Transactions - Networks Over Markets". *Journal of R&D Management,* Vol. 24(4) pp. 373-386.

BIOTEK (2001) *Priority Setting in Biotechnology under 8th Malaysia Plan.* Putrajaya, MOSTI.

BIOTEK (2003) *Biotechnology Cooperative Centre Achievement under 7th Malaysia Plan.* Putrajaya, MOSTI.

Bozeman, B. (2000) "Technology transfer and public policy: a review of research and theory." *Research Policy* Vol. 29, pp. 627-655.

Brown, G.E. (1992) "The objectivity crisis", *American Journal of Physics,* Vol. 60, pp. 779-81.

Bush, V. (1945) Science, the Endless Frontier. *A Report to the President.* Washington D.C., U.S. Government Printing Office.

Cabral, R. (1998) 'Refining the Cabral-Dahab Science Park Management Paradigm', *International. Journal of Technology Management,* Vol. 16, pp. 813-818;

CCTIT (1990) Industrial Technology Development - A National Plan of Action, MOSTI.

CIA (2005) *"CIA World Factbook – Malaysia (Economy)",* accessed on 15/11/2005 Available from WWW: http://www.cia.gov/cia/publications/factbook/geos/my.html

Clark, B. R. (1998) "The Entrepreneurial University: Demand and Response." *Journal of Tertiary Education and Management,* Vol. 4(1) pp. 5-16.

Cohen, L. and L. Manion (1995) *Research Methods in Education.* London, Routledge.

Cohen, W. M. and Levinthal, D. A. (1989) "Innovation and Learning: The two faces of R&D", *Economic Journal.* Vol. 99, pp. 569-596.

Comanor, W. S. and F. M. Scherer (1969) "Patent Statistics as a Measure of Technical Change." *Journal of Political Economy,* Vol. 77(3) pp. 392-398.

Coriat, B. and Orsi, F., (2002) "Establishing a New Intellectual Property Rights Regime in the United States: Origins, Content, Problems". *Research Policy*, Vol. 31, pp. 1491-1507.

Coulby, D. (2001) *The Knowledge Economy, the European Union and Universities.* Travelling Policy/Local Spaces: Globalisation, Identities and Education Policy in Europe, Keele University.

Di Gregorio, D. and S. Shane (2003) "Why do some universities generate more start-ups than others?" *Research Policy* Vol. 32, pp. 209-227.

Drucker, P. (1993) *The post-capitalist society.* New York, Harper Business.

DTI (2003) "Competing in the Global Economy: The Innovation Challenge". *Innovation Report.* Lord Sainsbury. London.

Durrani, T. S. and S. M. Forbes (2003) *The three legged stool - new modes of university-industry-government collaboration.* 13th International Conference on Management of Technology, Washington D.C.

EPU (1991) *Second Outline Perspective Plan 1991-2000.* Kuala Lumpur, Prime Minister's Department.

EPU (2001) *Eighth Malaysia Plan 2001-2005.* Putrajaya, Prime Minister's Department.

EPU (2001) *Third Outline Perspective Plan 2001-2010*. Putrajaya, Prime Minister's Department.

EPU (2003) *Mid-Term Review of the Eighth Malaysia Plan*. Putrajaya, Prime Minister's Department.

Etzkowitz, H. (2002) "Networks of innovation: science, technology and development in the triple helix era." *International Journal of Technology Management and Sustainable Development* Vol. 1(1): pp. 7-20.

Etzkowitz, H. and L. Leydesdorff (1997) *Universities in the Global Knowledge Economy: A Triple Helix of Academic-Industry-Government Relations*. London, Cassell.

Etzkowitz, H. and L. Leydesdorff (2001) "The Transformation of University-Industry-Government Relations." *Electronic Journal of Sociology,* Vol.5.

Etzkowitz, H., A. Webster, et al. (2000) "The future of the university and the university of the future: Evolution of ivory tower to entrepreneurial paradigm." *Research Policy* 29: 313-330.

Evers, H.-D. (2001) *Towards a Malaysian Knowledge Society*. 3rd International Malaysian Studies Conference, Institute of Malaysian and International Studies, September, Bangi, Malaysia.

Faulkner, W and Senker, J., (1994) "Making Sense Of Diversity: Public-Private Sector Research Linkages In Three Technologies". *Research Policy*, Vol. 23, pp. 673-695.

Freeman, C. and L. Soete (1994) *Work for all or mass unemployment?* London, Pinter.

Garduño, E. (2004) "Rethinking TT Metrics for Developing Countries". *Innovation*

Matters, Vol. 2.

Garlick, S. (2002) *Creative regional development: Knowledge based associations between universities and their places*. Paper presented at University and Community Engagement Forum. September 2002, Parramatta, Australia.

Geisler, E. (2002) "The Metrics of Technology Evaluation: Where We Stand and Where Should Go From Here." *International Journal of Technology Management* Vol. 24(4) pp. 341-374.

Gibbons, M., C. Limoges, et al. (1994) *The new production of knowledge: the dynamics of science and research in contemporary societies*. London, Sage.

Gibbons, M., Nowotny, H., Scott, P. (2002) *Re-Thinking Science: Knowledge and the Public in an Age of Uncertainty.* Cambridge, Polity Press.

Gibson, D.V., Conceicao, P., Quant, C. and Sung, T.K. (1998) 'Sharing learning and innovation worldwide', Paper presented at *Proceedings of 1998 Korean MIS Conference*, Seoul, pp. 661–670.

Gibson, D.V., Kozmetsky, G. and Smilor, R.W. (1992) *The Technopolis Phenomenon: Smart Cities, Fast Systems, and Global Networks*. Savage, MD, Rowman & Littlefield.

Gibson, D.V., Smilor, R.W. and Kozmetsky, G. (1988) *Creating the Technopolis, Linking Technology Commercialization and Economic Development*. Cambridge, MA, Ballinger.

GM (2000) *Széchenyi Terv: Ajövó pillérei* (trans. *Széchenyi Plan: Pillars of the Future*) Budapest, GM.

Godin, B. (1998) "Writing Performative History: The New Atlantis?" *Social Studies of Science* Vol. 28(3) pp. 465-483.

Goldfarb, B. and M. Henrekson (2003) "Bottom-up versus top-down policies towards the commercialisation of university intellectual property." *Research Policy* Vol. 32, pp. 639-658.

Grandstrand, O., (2000) “The shift towards intellectual capitalism - the role of infocom technologies”. *Research Policy,* Vol. 29, pp. 1061-1080.

Griliches, Z., (1990) “Patent Statistics as Economic Indicators: A survey”. *Journal of Economic Literature,* Vol. 28, pp. 1661-1707.

Grossman, G. and E. Helpman (1991) *Innovation and Growth in the World Economy.* Cambridge, MA, MIT Press.

Gustin, B. (1975) The *emergence of the German chemical profession.* Department of Sociology. Chicago, University of Chicago.

Guston, D. H. (2000) *Between Politics and Science.* Cambridge, Cambridge University Press.

Guston, D. H. and K. Kenniston (1994) "Updating the social contract for science." *Technology Review* Vol. 97, pp. 61-68.

Guston, D. H. and K. Kenniston (1994) ‘Introduction: The Social Contract for Science’. *The Fragile Contract: University Science and the Federal Government.* D. H. Guston and K. Kenniston (eds.), Cambridge MA, MIT Press.

Hall, A., Bockett G., Taylor., S, Sivamohan and Clark, N. (2001) “Why Research Partnerships Really Matter: Innovation Theory, Institutional Arrangements and Implications for Developing New Technology for the Poor”. *World Development,* Vol. 29, No. 5, pp. 783-797.

Hare, P.G. (1991) “Hungary: In Transition to a Market Economy”. *Journal of Economic Perspectives,* Vol. 5(4), pp. 195-201.

Havas, A. (2002) "*Conflicting Policy Needs in the First Decade of Transition: Macroeconomic and S&T Policies in Hungary, 1990-2000*". Report for the Macrotec project, Institute of Economics, Budapest, Hungarian Academy of Sciences.

HCSO (2003) *Statistics on Innovation, 2003*, accessed on 15/11/2005. Available from WWW: http://portal.ksh.hu/pls/ksh/docs/hun/xftp/idoszaki/pdf/innovacio03.pdf

Heller, M. A. and R. S. Eisenberg (1998) "Can Patents Deter Innovation? The Anticommons in Biomedical Research." *Science* Vol. 280(5364), pp. 698-701.

Henderson, R., A. Jaffe, et al. (1998) "Universities as a source of commercial technology: a detailed analysis of university patenting, 1965–1988". *Review of Economic Statistics.*: pp. 119–127.

Henrekson, M. and Rosenberg, N., (2001) "Designing Efficient Institutions for Science-Based Entrepreneurship: Lessons from the US and Sweden". *Journal of Technology Transfer*, Vol. 26, pp. 207-231.

Heston, A., R. Summers and B. Aten (2002) *Penn World Table Version 6.1,* Center for International Comparisons at the University of Pennsylvania (CICUP), Philadelphia.

Hii, H.-H. (2003) *Diagnosis and Prescriptions of a National Innovation System: the Case of Malaysia*. Paper presented at National Symposium of Science and Technology, Kuala Lumpur.

Hill, S., T. Turpin, et al. (1996) "South East Asia and the Pacific Rim". *World Science Report*. Paris, UNESCO, pp. 169-189.

HM Treasury (2003) *Lambert Review of Business-University Collaboration.* Sir Richard Lambert. London, Treasury.

HPO (2003) *Gazette of Patents and Trademarks, Hungary 2003*, accessed on 15/11/2005. Available from WWW: http://www.hpo.hu/English/adatbazis/kozlony_ab

Hughes, A. (2003) "Knowledge Transfer, Entrepreneurship and Economic Growth: Some Reflections and Implications for Policy in the Netherlands". Report for *CBR Research Programme 3 on Enterprise and SMEs - 'Universities and Local Systems of Innovation'*, ESRC Centre for Business Research, University of Cambridge Press.

Hunt, R.M., (1996) *Non-obviousness and the incentive to innovate: an economic analysis on intellectual property reform*. Philadelphia, Federal Bank.

Hwang, J.-S. (2002) *Does the concept of national innovation systems contribute to explaining economic performance?* Paper presented at DRUID Summer Conference : Industrial Dynamics of the New and Old Economy - who is embracing whom?, Copenhagen/Elsinore.

IMD (2004) *IMD World Competitiveness Yearbook 2004*. Geneva, IMD Office of Publcations

Intarakumnerd, P., Chairatana, P. and Tangchitpiboon, T. (2002) "National Innovation System in Less Successful Developing Countries: The Case of Thailand", *Research Policy,* Vol. 31, pp. 1445-1457.

ISIS (1999) *Knowledge-based Economy Master Plan*. Kuala Lumpur, MOF.

Jacobsson, S., (2002) "Universities And Industrial Transformation: An Interpretative And Selective Literature Study With Special Emphasis On Sweden". *Science and Public Policy*, Vol. 29(5) pp. 345-365.

Jencks, C. and D. Riesman (1968) *The Academic Revolution*. New York, Doubleday.

Judson, H. F. (1996) *The eighth day of creation: makers of the revolution in biology*. New York, Cold Spring Harbour Laboratory Press.

Kamogawa, A. (2003) "Higher Education Reform - Challenges towards a Knowledge Society in Malaysia." *African and Asian Studies* 2(4): 545-564.

Kim, L. (2003) Technology Transfer & Intellectual Property Rights - The Korean Experience. *UNCTAD-ICTSD Project on IPRs and Sustainable Development.*

Kline, S. and Rosenberg, N. (1986) "An Overview of Innovation," in Landau, R. and Rosenberg, N. (eds.) *The Positive Sum Strategy.* Washington, National Academy Press.

Konstadakopulos, D. (1999) *Reinforcing the Learning Behaviour of Small Innovative Firms of the ASEAN region: A New Approach to Regional Integration.* Tubingen, European Studies Programme.

Krishna, V. V. (1994) "Science Policies to Innovation Strategies." *Knowledge and Policy* Vol. 6(3-4), pp. 134-157.

Krishna, V. V., R. Waast, et al. (2000) "The Changing Structure of Science in Developing Countries." *Science, Technology and Society* Vol. 5(2), pp. 209-224.

Krishnamoorthy, M. (2005) "Slow patenting process threatens innovation". *The Star Malaysia*, 4 April 2005

Jolly, J.A. (1980) *The Stevenson-Wydler Technology Innovation Act of 1980 P.L. 96-480.* Journal of Technology Transfer, Vol. 5(1), pp. 69-80

Lai, M.-C. and S.-F. Yap (2004) "Technology development in Malaysia and the newly industrializing economies: a comparative analysis." *Asia-Pacific Development Journal* Vol. 11(2)

Landes (1998) *The Wealth and Poverty of Nations: Why Some are so Rich and Some are so Poor*, New York, NY, W.W. Norton & Company.

Lee, S. K. and D. K. Gibson (2002) "Towards Knowledge-based Economy in Korea: Metrics and Policy.". *International Journal of Technology, Policy and Management,* Vol. 2(3)

Lee, S., S. I. Chang, et al. (2000) *The Theory and Practice of Knowledge-Based Economy,*. Seoul, Korea Institute for Industrial Economics & Trade (KIET)

Leydesdorff, L. and H. Etzkowitz (2001) "The Transformation Of University-Industry-Government Relations." *Electronic Journal of Sociology.*

Likert, R. (1932) "A technique for measuring attitudes." *Archives of Psychology* Vol. 140.

Liu, X. and S. White (2001) "Comparing innovation systems: a framework and application to China's transition context." *Research Policy* Vol. 30 pp.1091-1114

Lopez, L. (2005) "Malaysia faces test in overhaul of state-controlled companies". *The Wall Street Journal,* 11 August 2005

Lowe, R. A. and S. K. Quick (2004) "Measuring the Impact of University Technology Transfer: A Guide to Methodologies, Data needs and Sources." *Journal of the Association of University Technology Managers* Vol. 16(1), pp. 43-59.

Luhmann, N. (1982) "The world society as a social system." *International Journal of General Systems* Vol. 61(3), pp. 987-997.

Lundvall, B.-Å. and B. Johnson (1994) "The Learning Economy." *Journal of Industry Studies* Vol. 1(2), pp. 23-42.

Lynn, L.H., Reddy, N.M., Aram, J.D., (1996) "Linking Technology And Institutions - The Innovation Community Framework". *Research Policy* Vol. 25(1) pp. 91-106.

MacDonald, S. (1986) "Theoretically Sound: Practically Useless? Government grants for Industrial R&D in Australia". *Research Policy,* Vol. 15, pp. 269-283.

Malairaja, C. and G. Zawdie (2004) "The 'black box' syndrome in technology transfer and the challenge of innovation in developing countries - The case of international joint ventures in Malaysia." *International Journal of Technology Management and Sustainable Development* Vol. 3(3), pp. 233-251.

Malaysian Dept. of Statistics (2003) *Macroeconomic Indicators for Malaysia* 2003, accessed on 24/2/2004. Available from WWW: http://www.statistics.gov.my/english/frameset_keystats.php

Mani, S. (2004) "Financing of Innovation – A Study of Various Institutional Mechanisms in Malaysia and Singapore.". *Journal of Technology Innovation* Vol. 12(2), pp. 185-208.

Mans, D. (1996) Indonesia - Industrial Technology Development for a Competitive Edge. *Indonesia Discussion Paper Series*. Washington D.C., World Bank

Mansfield, E. and Lee, J-Y ., (1996) "The Modern University: Contributor To Industrial Innovation And Recipient Of Industrial R&D Support". *Research Policy,* Vol. 25, pp. 1047-1058.

Martin, B. (2003) *The Changing Social Contract for Science and the Evolution of Knowledge Production.* A. Geuna, A. J. Salter and W. E. Steinmuller (eds.). Cheltenham, Edward Elgar.

Martin, B. and A. Salter (2001) "The economic benefits of publicly funded basic research: a critical review." *Research Policy* Vol. 30, pp. 509-532.

MASTIC (2003) *National Survey of Innovation 2000-2001*. Putrajaya, MOSTI.

MASTIC (2003) *National Survey of Research & Development 2002*. Putrajaya, MOSTI.

MASTIC (2004) *Science and Technology Knowledge Productivity in Malaysia -*

Bibliometric Study 2003. Putrajaya, MOSTI.

MIGHT (2004) "The National Brain Gain Programme : Strengthening Human Capital for Science and Technology". *Fusion,* Vol. 8, October 2004, pp. 8-9

MIGHT (2005) *Malaysian Industry-Government Group for High-Technology Background.* Accessed on 14/3/2006, available at WWW: http://www.might.org.my/might/index.php?option=com_content&task=view&id=12&Itemid=139

MIPC (2005) *Intellectual Property Corporation of Malaysia – Statistics.* Accessed on 14/3/2006, available at WWW : http://www.mipc.gov.my/index.php?option=view&id=27

Md. Nor, A. (1996) *Commercialisation of Inventions and Transfer of Technology in the ASEAN Countries - Experience of Malaysia.* Paper presented at WIPO-IFIA International Symposium on the Commercialisation of Patented Inventions, Kuala Lumpur.

MTDC (2004) "Bridging University Research Products with Industry". Paper presented at *University-Industry Forum : Commercialization of R&D for Global Competitiveness*, October 2004, Kuala Lumpur

MTDC (2005) *Malaysian Technnology Development Corporation – Corporate Profile.* Accessed 14/3/2006, available at WWW: http://www.mtdc.com.my/ind.htm

MTDC (2005) *Malaysian Technnology Development Corporation – Approved Projects.* Accessed 14/3/2006, available at WWW: *http://www.mtdc.com.my/grant/crdf_approve*

Molas-Gallart, J., Salter, A., Patel, P., Scott, A., Duran, X., (2002) *Measuring Third Stream Activities: Final Report to the Russell Group of Universities*, Science and Technology Policy Research Unit, University of Sussex.

MOSTE (2001) *Users' Manual for IRPA Programme - Eighth Malaysia Plan.* Putrajaya, MOSTE.

MOSTI (2002) *The Second National Science and Technology Policy and Plan of Action.* Putrajaya. Penerbit MASTIC.

MOSTI (2005) *MOSTI Strategic and Commercialisation Division – Commercialised R&D Projects.* Accessed at 14/3/2006, available at WWW : http://www.mosti.gov.my/opencms/export/MostePortal/SdanP/BDUrndEn.html

Mowery, D. and Rosenberg, N. (1989) *Technology and the Pursuit of Economic Growth,* Cambridge, Cambridge University Press.

Mowery, D. C. and B. N. Sampat (2003) "The Bayh-Dole Act of 1980 and University-Industry Technology Transfer: A Model for Other OECD Governments?" *Journal of Technology Transfer,* Vol. 30(1-2), pp. 115-127.

Narin, F. and A. Breitzman (1995) "Inventive productivity." *Research Policy* Vol. 24(4), pp. 507-519.

Nonaka, I. (1992) "Survey Introduction", in Asian Productivity Organisation, *Management Dynamism, A Study of Selected Companies in Asia,* pp. 1-8.

Nowotny, H., P. Scott, et al. (2001) *Rethinking Science: Knowledge and the Public in an Age of Uncertainty.* Cambridge, Polity Press.

OECD (1996) "The Knowledge Based Economy". *1996 Science, Technology and Industry Outlook.* Paris, OECD.

OECD (2004) *Export shares of high and medium technology industries.* accessed on 15/11/2005. Available from WWW: http://titania.sourceoecd.org/vl=5823791/cl=12/nw=1/rpsv/scoreboard/f08.htm

OECD (1997) *Oslo Manual - Proposed Standard Practice for Collecting and*

Interpreting Technological Innovation Data. Paris, OECD.

OM (2000) *Science and Technology Policy - 2000.* Budapest, Oktatási Minisztérium.

O'Malley, M. A., G. R. McOuat, et al. (2002) *The Triple Helix Account of Scientific Innovation: A Critical Appraisal.* 4th Triple Helix Conference, Copenhagen and Lund.

OMFB (1995) *Akormány músoncepciója, Elóterjesztés a kormány részére* (trans. *The Government's Concept on Technological Development: A Proposal for the Government*) *OMFB Híradó*, Budapest.

Paasi, M. (1998) "Efficiency of innovation systems in the transition countries." *Economic Systems.* Vol. 22(3) pp. 217-234.

Pavitt, K. (1991) "What makes basic research economically useful." *Research Policy* Vol. 20, pp. 109-119.

Pavitt, K. (1998) "The social shaping of the rational science base." *Research Policy* Vol. 27, pp. 793-805.

Porter, M. and S. Stern (2002) "National Innovative Capacity". *Global Competitiveness Report 2001-2002.* World Economic Forum. New York, Oxford University Press.

Powell, W.W., Owen-Smith, J. (1998) "Universities and the Market for Intellectual Property in the Life Sciences", *Journal of Policy Analysis and Management,* Vol. 17, pp. 253–277.

Prahalad, C. K. (1998) "Managing Discontinuities: The Emerging Challenges", *Research Technology Management.* Vol. May-June.

Radosevic, S. (1999) "Transformation of science and technology systems into systems of innovation in central and eastern Europe: the emerging patterns and determinants." *Structural Change and Economic Dynamics* Vol. 10(3-4), pp. 277-

320.

Rasiah, R. (2002) "Systemic Coordination and Human Capital Development: Knowledge Flows in Malaysia's MNC-driven Electronics Clusters." *Transnational Corporations* Vol. 11(3), pp. 89-130.

Ratnam, K. J. (2004) *The Scientific Enterprise*. Penang, Penerbit USM.

Rausch, L.M. (1998) "High-tech industries drive global economic activity". *Issue Brief.* Washington, DC, Division of Science Resources Studies, National Science Foundation.

Razak, D. A. (2005) *Revolusi Pendidikan: Merekayasa sebuah universiti - kes Universiti Sains Malaysia*. Penang, Penerbit USM.

Ritchie, B. K. (2005) "Coalitional Politics, Economic Reform, and Technological Upgrading in Malaysia." *World Development* Vol. 33(5), pp. 745-761.

Romer, P. R. (1990) "Endogenous technical change." *Journal of Political Economy* Vol. 98, pp. 71-102.

Romijn, H.A. and I. Taksz, (1998) 'Science and Technology Development in Countries in Economic Transition: The Case of Hungary'. Report prepared for the European Union Project "*Science and Technology Policies in Developing and Transition Countries: Reform and Technical Co-operation with Europe*", Oxford, Queen Elizabeth House.

Sábato, J.A. and Botana, N. (1968) "La Ciencia y la Tecnología en el Desarrollo Futuro de America Latina." Paper presented at *The World Order Models Conference*, Bellagio, Italy, 25-30 September 1968.

Sábato, J.A. (1997) Bases para un régimen de tecnología. *Redes*, Vol. 4(10), pp. 119-137.

Sampat, B. N., D. C. Mowery, et al. (2003) "Changes in University Patent Quality After the Bayh-Dole Act: A Re-Examination." *International Journal of Industrial Organization* Vol. 21(9), pp. 1371-1390.

Schumpeter, J. (1934) *The Theory of Economic Development*, Harvard University Press, Cambridge, Massachussets.

Sedaitis, J.B. (1997) *Commercializing High Technology: East and West*. Lanham, MD, Rowman & Littlefield Pub. Inc.

Shane, S. (2002) "Encouraging university entrepreneurship? The effect of the Bayh-Dole Act on university patenting in the United States." *Journal of Business Venturing* Vol. 19.

Shinn, T. (2002) "The Triple Helix and new production of knowledge: pre-packaged thinking on science and technology." *Social Studies of Science* Vol. 32(4), pp. 599-614.

Siegel, D.S., Waldman D. and Link, A., (2003) "Assessing the Impact of Organizational Practices on the Relative Productivity of University Technology Transfer Offices: An Exploratory Study". *Research Policy* Vol. 32(1) pp. 27-48.

Sizer, J. (2001) "Research and the Knowledge Age." *Tertiary Education and Management* Vol. 7.

SMIDEC (2004) "Industrial Needs for Emerging Technology and Quality of Human Resources" Paper presented at *University-Industry Forum : Commercialization of R&D for Global Competitiveness*, October 2004, Kuala Lumpur

Smith, A. (1986) *The Wealth of Nations (1776)* London, Penguin Books Ltd.

Sopiee, N. (2002) "Introducing the Knowledge Economy Master Plan". *New Straits Times,* Friday, July 15 2002.

Spangenberg, J. F. A., Starmans, R., Bally, Y. W., Nijhuis, F. J. N. and Van Dorp, C. A. F. (1990) "Prediction of Scientific Performance in Clinical Medicine". *Research Policy,* Vol. 19, pp. 239 - 255.

Stiglitz, J. E. (1999) *Public Policy for a Knowledge Economy,* Centre for Economic Policy Research, Department for Trade and Industry. London, DTI

Sung, T. K. and D. K. Gibson (2000) *Knowledge and technology transfer: levels and key factors*. Paper presented at 4th International Conference on Technology Policy and Innovation, Curitiba, Portugal.

Teese, D. J. (1998) "Capturing value from knowledge assets: the new economy, markets for know-how, and intangible assets." *California Management Review* Vol. 40(3), pp. 55-79.

Thiruchelvam, K. (2004) "Towards a Dynamic National System of Innovation in Malaysia: Enhancing the Management of R&D in Public Research Institutions and Universities." *Journal of Technology Innovation* Vol. 12(2), pp. 127-150.

Thursby, J. G. and M. C. Thursby (2003) "'*University Licensing under Bayh-Dole: What are the Issues and Evidence?"* Paper presented at HBS - MIT Sloan Free/Open Source Software Conference: New Models of Software Development, Boston.

Tidd, J. and M. Brocklehurst (1999) "Routes to Technological Learning and Development: An Assessment of Malaysia's Innovation Policy and Performance." *Technological Forecasting and Social Change.* Vol. 62.

TPM (2004) *Technology Park Malaysia – About Us*. Accessed on 14/3/2006, available at WWW: http://www.tpm.com.my/about.htm

Tornatzky, L. G. (2001) "Benchmarking University-Industry Technology Transfer: A Six Year Retrospective." *Journal of Technology Transfer* 26.

Turnbull, D. (1994) "Local Knowledge and Comparative Scientific Traditions."

Knowledge and Policy 6: 29-54.

Turpin, T. and X. Liu (2000) "Balanced Development: the Challenge for Science, Technology and Innovation Policy". *Contemporary Development and Issues in China's Economic Transition*. C. Harvie, Macmillan.

Turpin, T., C. Martinez-Fernandez, et al. (2002) "*Riding the Waves of Policy: the 'New Production of Knowledge' and Implications for Developing Economies*". Paper presented at Development Through Knowledge? A new look at the global knowledge-based economy and society, Geneva.

U.S Congress (1980) *The Patent and Trademark Law Amendments Act,* (P.L. 96-517)

UNDP (2005) *Human Development Report 2005.* United Nations, New York.

UNICO (2003) *Annual Survey on University Technology Transfer Activities, Financial Year 2002*, Nottingham University Business School, Nottingham.

USPTO (2003) *Patent Counts by Country / State and Year, All Patents, All Types, January 1, 1977 - December 31, 2002.* Washington, D. C., United States Patent and Trade Mark Office.

Vishvanathan, S. (2001) "*Challenges of Globalisation: South African debates with Manuel Castells*". The Grand Sociology of Manual Castells, J. Muller, N. Cloete and S. Badat (eds.) Capetown, Longman: pp. 35-49.

Wafa, S. A., A. R. Kechik, et al. (1999) "Performance and Problems of International Joint Ventures in Malaysia". *Malaysian Management Review*. Vol. 34.

Walsh, V. (1984) "Invention and Innovation in the Chemical Industry: Demand Pull or Discovery Push". *Research Policy,* Vol. 13(4), pp. 211-234.

Weingart, P. (1997) "From Finalization to Mode 2: Old Wine in New Bottles?"

Social Science Information Vol. 34(4), pp. 591-613.

WHO (2001) *World Health Report 2001.* Geneva, WHO Office of Publications.

Wikstrom, S. and Normann, R. (1994) *Knowledge and Value: A New Perspective on Corporate Transformation.* London, Routledge.

Wong, P.-K. (1999) *National Innovation Systems for Rapid Technological Catch-up: An analytical framework and a comparative analysis of Korea, Taiwan and Singapore*. Paper presented at DRUID Summer Conference, Rebild.

World Bank (1998) "Knowledge for Development" *World Development Report.* Washington D.C. World Bank.

World Bank (2003) *World Development Indicators 2003,* Washington, D. C., World Bank.

World Economic Forum (2004) *Global Competitiveness Report* 2003-2004. Oxford University Press.

Zhu Z. (2000*) Collection of the technical materials of the national 863 high-tech project of China'*. Institute of Hydrobiology, Chinese Academy of Sciences, Wuhan.

Zìman, J. (1994) *Prometheus Bound: Science in a Dynamic Steady State*. Cambridge, Cambridge University Press.

Ziman, J. (1995) *Of one mind: the collectivization of science*. New York, American Institute of Physics.

Zucker, L., Darby, M. and Brewer, M.,(1998) "Intellectual Human Capital and the Birth of US Biotechnology Enterprises". *American Economic Review*, Vol. 88(2) pp. 290-306.

Appendices

Appendix 1 - Draft version of questionnaires

Patent System

1. How much does it typically cost to patent a technology for 12 months? How much till licensing?
2. How long does it typically take in months for a patent to get granted?
3. How many patents are filed by universities? How many are filed by industry through licensing?
4. When in the patenting process is technology licensed after invention disclosure?
5. Is the Utility Innovation Certificate used as IP protection? Why?
6. When will Malaysia fully ratify the Patent Convention Treaty? Is the current status driving away patenting activities? How full ratification of PCT affect the current patenting situation?
7. How large is the backlog of unexamined patent applications? Is this driving away patent activities?
8. What was the impact of the Budget 2004 recommendation that there be no charges levied on patents registered by local researchers?
9. Where is the patent system currently lacking? Any recommendations on improving the current practice?

Research / Ideas / Innovation

1. How important is the prospect of commercializing future findings in carrying out research? Is publishing research findings the main priority instead of commercialisation?

2. Is there a sound research management system in place to monitor developments in faculty research? Is this used to spot potential commercialisation opportunities?

3. Is there sufficient commercialisation expertise and skills within the faculty and staff? What are the steps taken to increment this?

4. Do directions for collaborated research mainly originate from market pull or technology push? Does the originator finally take-up the finished technology?

5. How does the initiative to collaborate usually come about?
   a) concerted effort from various parties
   b) existing contacts
   c) research participation
   d) other

6. What is the institutional policy regarding selecting partners for collaboration? What are the specific policies on collaborating with :
   a) Start-ups
   b) SMEs
   c) Local corporations
   d) Foreign multinationals

7. Is there a mechanism available for industry to monitor and keep up with research developments?

8. Is the current pay system rewarding enough to stimulate research collaboration? What is the best way to address this situation?

9. What are the difficulties in obtaining funding through Intensification of Research in Priority Areas grants? Where could this be changed to facilitate effective technology transfer?

10. Would obligation to protect and commercialise findings from government funding be a barrier to research?

University Governance & Structure

1. What is the employment policy on academic staff regarding :
    a) required working schedule
    b) regulation of personal time

2. Does the university provide time for academics to interact with business? How much of this time is actually used?

3. What percentages of academics have previous industrial experience? How is their knowledge used in teaching and research?

4. What percentages of alumni bring industry relationships to the university?

5. At what level, if any, is industry represented in the administration and operations of the university?

6. Is there a clear IP management policy practised throughout the university? Who is in charge of managing and implementing this policy?

Legislation

1. Have recent legislations/policies been effective in perpetuating :
    a) increased standard of higher education
    b) high socio-economic impact
    c) technology transfer
    d) funding stream for higher education / R&D
    e) others

2. How apparent is this legislation in making strategic decisions in day-to-day operations?

3. Has current legislation encouraged further collaboration between industry and academia?

4. Has legislation clarified IP ownership and industry participation?

5. What are the main financial and time constraints in keeping up and enforcing current legislation?

6. How is legislation a barrier to :
    a) acquiring research funds / incentives
    b) contracts of employment
    c) autonomy of universities
    d) FDI policies

7. How can current legislation be changed to facilitate effective technology transfer?

Appendix 2 - Final version of questionnaires

RESEARCH QUESTIONNAIRE

Research Student:	***Riaz Abdul Razak***
Student ID :	***185350***
Program :	***MPhil.***
Faculty :	***School of Engineering***
Supervisor :	***Prof. R.M. Clement***
Institution :	***University of Wales Swansea***

I am a Masters (MPhil.) in Engineering student at the University of Wales Swansea currently undertaking a study in "T*echnology Transfer from Public Universities – An Exploratory Study of the Malaysian Situation*" as partial fulfilment of the requirements for my degree.

This research questionnaire contains a series of statements evaluating your involvement in technology transfer activities. As this is **strictly** an **academic study**, all responses will be treated as **confidential.** Please answer honestly by choosing the best response that represents your feelings to each statement. Your time and cooperation are highly appreciated

Should there be any enquiries, please feel free to contact :

Riaz Abdul Razak : **019 3593682**

Prof. R.M. Clement - **+44 1792 295685**

Ref. Code :

DEMOGRAPHIC PROFILE OF RESPONDENT

Name : ____________________________________

Gender :

☐ Male
☐ Female

Age group :

☐ < 20 years
☐ 20 – 29 years
☐ 30 – 39 years
☐ 40 – 49 years
☐ ≥ 50 years

Designation / Position :

☐ Researcher
☐ Inventor/innovator
☐ Lecturer
☐ Post graduate student
☐ Administrator
☐ IP practitioner
☐ Venture capitalist
☐ Others (please specify) ____________________

Institution / Organisation : ____________________________

Department / Faculty / Unit : ____________________________

Highest Academic Qualification :

☐ PhD
☐ Masters
☐ Degree
☐ Others

RESEARCH PROJECT DETAILS

Project Title : ______________________________

Project Leader : ______________________________

Size of Project Team : ______________________________

Research Classification Area :

Experimental Applied Research :

- ☐ **Agriculture & Food**
- ☐ **Natural Resources & Environment**
- ☐ **Manufacturing & Services**
- ☐ **Social Transformation**
- ☐ **Knowledge Advancement**

Priority Research :

- ☐ **Manufacturing**
- ☐ **Plant Production & Primary Products**
- ☐ **Information & Telecommunication**
- ☐ **Health**
- ☐ **Education & Training**

Strategic Research :

- ☐ **Design & Software Technology**
- ☐ **Nanotechnology & Precision Engineering**
- ☐ **Specialty Fine Chemicals Technology**
- ☐ **Optical Technology**

Others : ______________________________

Site of Research

- ☐ **University Campus**
- ☐ **Research Institution**
- ☐ **Industry / Sponsors Premises**
- ☐ **Others (please specify)** ____________________

Source / Amount of Funding :

- ☐ **IRPA Grants :** ______________
- ☐ **University Grants :** ______________
- ☐ **Other Public/Government Grants :** ______________
- ☐ **Private Sponsors :** ______________
- ☐ **Industry Clients :** ______________
- ☐ **Others (please specify) :** __________________________

Duration of Research

- ☐ **Less than 1 year**
- ☐ **1 – 3 years**
- ☐ **3 – 5 years**
- ☐ **More than 5 years**

Purpose of research output (please tick all that apply) :

- ☐ **Academic fulfilment**
- ☐ **Requirement for promotion**
- ☐ **Component of further research**
- ☐ **Fulfilling needs of industry**
- ☐ **Commercialisation of findings**
- ☐ **Others (please specify)** __________________________

Intellectual Property Protection

a) **Number of patents you have applied for** ____________
b) **Number of industrial designs registered** ____________
c) **Copyrights and trademarks registered** ____________
d) **Utility innovation certificates** ____________

RESEARCH ACTIVITY

1. **Collaborative research between university and industry mainly originate from (Please tick only one)**

   ☐ university
   ☐ industry
   ☐ others (please specify) ______________________________

2. **The direction of collaborative research is often**

   ☐ University driven
   ☐ Industry driven
   ☐ Others (please specify) ______________________________

3. **Have you been personally involved with university-industry collaborative efforts?**

   Yes No

4. **If yes, what was/is the nature and frequency of these collaborations?**

	never				always
a) contract research	1	2	3	4	5
b) consultancy	1	2	3	4	5
c) training	1	2	3	4	5
d) licensing research output	1	2	3	4	5
e) others (please specify) ______________________	1	2	3	4	5

5. **Research activities are well monitored by a designated unit in your university.**

   1 2 3 4 5

   (strongly disagree) (strongly agree)

6. **Is the monitoring system able to successfully identify research with potential commercial value?**

   1 2 3 4 5

   (not successful) (very successful)

7. **How much expertise and marketing skills are there within the university with respect to commercializing research output?**

1 2 3 4 5

(none at all) (more than enough)

8. **Is there any mechanism available for <u>industry</u> to monitor and keep up with research developments?**

Yes No

If yes, please specify : ______________________________

____

9. **Are there enough incentives to reward and stimulate university-industry collaborations?**

Yes No

If no, what is the best way to address this situation?

____

10. **What are the difficulties in obtaining funding through Intensification of Research in Priority Areas (IRPA) grants? (Please tick all that apply)**

- ☐ Application not within priority/target areas
- ☐ Unsatisfactory write-up of proposal as judged by MOSTI
- ☐ No significant evidence of linkages with industry
- ☐ Not enough proper R&D proposed to justify grant
- ☐ Little or no follow-up from MOSTI on application
- ☐ Bureaucracy in dealing with relevant departments
- ☐ No difficulty found
- ☐ Others (please specify)______________________

Do you have any suggestions to increase efficiency of grant allocations towards facilitating transfer of technology?

____

____

INTELLECTUAL PROPERTY (IP)

11. How much knowledge of IP do you have?

1 2 3 4 5

(none) (highly knowledgeable)

12. Do you have any knowledge of any IP policies, laws and regulations in

i) Malaysia Yes No

ii) Our organisation? Yes No

13. I am aware of the department/person(s) to contact regarding IP matters in my organisation.

Yes No

14. Are you aware of the guidelines regarding the distribution of income from commercialisation of IP as laid out by the Min of Education and the Public Services Department (JPA)?

Yes No

15. If you were to patent your invention, what percentage of revenue allocation do you think is reasonable for the parties involved/?

Inventor/Innovator/researcher ...... %

Sponsor/investor ...... %

University ...... %

Inventor/Innovator/researcher's Department ...... %

16. How do you feel about the way your university has managed IP assets generated by their researchers?

1 2 3 4 5

(not satisfied at all) (very satisfied)

17. The IP from research that has been funded by the government should be protected through patenting.

1 2 3 4 5

(strongly disagree) (strongly agree)

18. There should be legislation to ensure that government-funded research should be commercialised by the university.

1 2 3 4 5

(strongly disagree) (strongly agree)

19. Are there any mechanisms to settle any disputes regarding IP rights and ownership?

Yes No

20. I have personally benefited from taking advantage of my IP rights through :

____

End of questionnaire

Thank you for your time.
Your cooperation is highly appreciated.